7.0 SOLUTION DEVELOPMENT

7.1 INTRODUCTION

7.1.1 Introduction to Solution Development

The solutions presented in this section were developed to address multiple needs within the Cool Creek watershed. These needs include:

- Flood control at major roadway crossings
- Neighborhood (local roadway) flood control
- Streambank erosion control
- Regional detention needs
- Land use and planning

Solutions were *not* considered for the following problems:

- Flooding at private crossings
- Flooding at bridges currently being replaced or under consideration for replacement in the near future
- Structures that meet currently-accepted stormwater design guidelines and do not negatively impact the 100-year floodplain

7.1.2 Upper Reaches versus Lower Reaches – Overview of Proposed Solutions

Upper Reaches:

Reduce peak flows during more frequent (i.e. 1-year and 2-year) rainfall events by constructing new and retrofitting existing detention basins. Although these detention facilities may not serve as flood control devices, they will serve as water quality enhancement features, providing the following benefits:

- Reducing sediment, nutrients, and metals in stormwater runoff
- Reducing flow rates resulting from more frequent storm events, thus reducing the erosive forces on downstream open channels
- Providing habitat for aquatic and non-aquatic species
- Reserving open space in the watershed for public access, recreation, and education

Provide adequate conveyance at major roadway crossings. Based on available hydraulic information, there are more severe conveyance problems in the upper reaches of Cool Creek and its immediate tributaries. Replacing inadequate bridges and culverts will help to enhance public safety by reducing the likelihood of roadway overtopping during major storm events and reduce floodplain impacts on property owners.

Lower Reaches:

Many downstream reaches of Cool Creek currently experience severe erosion problems. This is largely due to the following:

- ***Aggregate effects of development in the upstream portions of the Cool Creek watershed.*** Higher peak flows occur more frequently and subject channel streambanks to excessive erosive forces. Numerous detention ponds have been constructed in the watershed. These ponds provide effective peak flow control for larger storm events, but do not adequately restrict flow rates for more frequent (i.e. 1-year and 2-year recurrence interval) storm events. These more frequent rainfall events generally dictate the tendency for channel erosion.

- ***Development at or near existing channels.*** Manmade features, such as residential structures, retaining walls, patios, foot bridges, and decks have been constructed within the floodplain and result in flow restrictions, higher velocities, and promote downstream streambank erosion.

Construction near channel (right side of photo) constricts flood waters and promotes downstream erosion. Landscape debris (left side of photo) prevents the efficient flow of water and traps additional debris, creating a dam.

The proposed improvements to the Cool Creek watershed will be an important first step in reducing nuisance flooding, preventing flooding at major roadways, and reducing streambank erosion. Land use planning within the entire Cool Creek watershed should be implemented to minimize the impacts of development on stormwater pollution, erosion potential, and flooding potential. This will help to ensure a positive return on the capital investments recommended in this section (see discussion on recommended land use and planning policies in Section 7.8).

7.2 DESIGN CRITERIA AND CONSTRAINTS

7.2.1 Erosion Prevention

Channel erosion is a key factor in water quality degradation and presents numerous problems for stormwater infrastructure. The absence of vegetation along channel banks, when combined with high flow velocities, results in channel deepening, widening, and incision. This process is accelerated in areas of rapid land development, due to changing flow patterns, increased sediment from construction activities, and inadequate culverts and bridges. The long-term quality of Cool Creek will be improved by reducing steambank erosion. Erosion prevention can consist of the following methods:

- Streambank stabilization of severely eroded areas (Section 7.6)
- Hydrologic modification using regional detention (Section 7.7)
- Monitoring and long-term maintenance of moderately eroded areas
- Modifying the detention policy to better control and detain runoff from the 1-year and 2-year storms (Section 7.8)

Numerous erosion areas exist along the entire reach of the Cool Creek and its tributaries. The cost to repair each identified erosion area would be prohibitive. As such, it was necessary to classify each erosion area as minor, moderate, or severe. This classification allowed the separation of erosion areas posing the greatest threat to public safety and private property from those areas not needing immediate attention.

Severe erosion areas consisted of specific channel segments with evidence of any or all of the following:

- Deep, undercut channel banks
- Absence of vegetation along entire eroded bank
- Steep bank slope (exceeding 1:1 ratio and approaching vertical)
- Close proximity of manmade structures

Seven separate severe erosion sites have been identified in the Cool Creek watershed. Of these sites, five are along the Cool Creek. Two sites are located on tributaries. These sites are discussed in more detail in Section 7.6.

Minor and moderate erosion areas showed initial signs of channel undercutting and loss of vegetation. These areas have been identified on the Cool Creek Inventory Maps and should be monitored in the future for any negative physical changes.

HEC-RAS v. 3.0 was used to estimate peak flow velocities for seven (7) individual sites experiencing *severe erosion* (using HEC-2 data from the most recent Cool Creek Flood Insurance Study, supplemented with GIS contour data). As discussed in Section 7.6, the calculated velocities have been used to develop recommendations for streambank improvements for each identified area. Peak flow velocities resulting from the *10-year* recurrence interval storm were used to evaluate each erosion area and to determine appropriate erosion prevention measures.

7.2.2 Flood Control

Numerous flood-prone areas have been identified through past resident complaints, FEMA floodplain maps, and independent hydraulic analysis. Many of the flood-prone areas are caused by private driveway crossings and are located in remote, undeveloped portions of the watershed. Proposed flood control solutions have been prepared only for major public roadways and other public rights-of-way with significant known flooding problems.

Neighborhood Flooding. Typical municipal standards were employed for solution development in identified neighborhood flooding areas. Culverts, storm sewer pipes, and open channels were designed to convey the runoff generated from a 10-year recurrence interval rainfall event. In developing the proposed solutions for neighborhood flooding areas, it was assumed that access to private property could be secured through permanent and/or temporary construction easements.

The proposed solutions were developed using HEC-RAS and HY8 (HY8 is a culvert analysis program). GIS data were used to determine approximate site characteristics and identify potential construction limitations.

Roadway (Bridge) Overtopping. INDOT design standards were employed for bridges identified as flood-prone. The hydraulic capacities of 151st Street and 171st Street bridges (each at Cool Creek) and Cherry Street, Gurley Street, and Park Street (each at Anna Kendall Drain) were analyzed for both the 25-year and 100-year recurrence interval rainfall events. INDOT standards specify that a bridge with an Average Daily Traffic (ADT) count between 1,000 and 3,000 shall convey stormwater runoff generated from a 25-year recurrence interval rainfall event without roadway flooding. *The above crossings should fall within the referenced ADT range.* For a 100-year event, the upstream hydraulic grade line shall be less than or equal to 0.10 feet above that under existing conditions. The proposed modifications for the above crossings, with the exception of Gurley Street (ADT < 1,000), were based on these criteria.

HEC-RAS v. 3.0 was used to develop a hydraulic model for the existing and proposed bridge geometries. Existing bridge geometries and cross-sectional data for Cool Creek were based on the pending 2003 update of the Flood Insurance Study (HEC-2 model). Cross-sectional and roadway crossing geometries for the Anna Kendall Drain were based on approximations developed using the GIS contour and roadway elevation data.

Excessive Hydraulic Restrictions at Roadway Crossings. The US 31 crossing (Highway Run), the SR 32 (Main Street) crossing (J.M. Thompson Drain), and several culverts in the vicinity of Walter Street/Walter Court (Highway Run) create significant headwater, resulting in wide floodplains upstream of each location, affecting numerous residential structures. HEC-RAS was used to determine necessary culvert replacements that would lower the 100-year water surface elevations upstream of selected culverts along the Highway Run and J.M. Thompson Drain. Although these culverts do no overtop during the 100-year event, they result in significant upstream flooding. As such, their replacement is recommended.

7.3 COST ESTIMATING APPROACH

This section describes the basis for determining estimated costs for the proposed solutions. At the end of this section is a summary of the estimated costs for each proposed improvement. These cost estimates are based on typical construction bids for similar work and information available from governmental sources.

7.3.1 Streambank Restoration

Streambank restoration costs vary widely, largely due to the numerous materials and construction techniques currently available. The United States Environmental Protection Agency (USEPA) and the Natural Resource Conservation Service (NRCS) provide useful information on typical costs for streambank restoration work. Unit prices were based on guidance from these sources and available bid history on similar pay items. Estimated restoration costs were adjusted to account for specific site characteristics, such as channel depth, estimated flow velocities and site accessibility/mobilization.

7.3.2 Storm Sewers and Appurtenances

Storm sewer estimates were based on bid tabulations for similar construction work. Adjustments were made for specific site characteristics and site accessibility.

7.3.3 Pavement Re-grading and Bridge/Culvert Removal and Replacement

Pavement re-grading and bridge removal/replacement costs were based on bid tabulations for similar construction work. Cost estimates for bridge/culvert replacement include additional costs for soil testing, structural analysis, excavation, pavement restoration, riprap, boring/jacking (if necessary) and general site restoration.

7.3.4 Detention Facilities

Detention pond construction cost estimates were based on published ranges available from the USEPA and other sources.

The estimated cost to retrofit the detention basin upstream of the Conrail Railroad (Anna Kendall Drain) was modified to reflect additional costs required to satisfy the Indiana DNR *General Guidelines for New Dams and Improvements to Existing Dams in Indiana*.

The detention pond cost estimates do *not* include land acquisition costs, unless specifically noted.

7.3.5 Construction Contingency

A construction contingency of twenty (20) percent was added to each construction estimate to account for unforeseeable site specific items that cannot be identified at the conceptual design level.

7.3.6 Non-Construction Costs

Each proposed improvement will require field survey, detailed site condition analysis, design report preparation, regulatory permitting, plan and specification preparation, and construction administration. Legal and administrative costs are also typically included on proposed improvement projects. For each proposed solution, it was estimated that an additional twenty (20) percent would be required for these non-construction costs. Land acquisition costs were assumed to be $15,000 per acre, unless the land was generally not conducive to development, in which case it was assumed to be $5,000 per acre.

Table 7-1 contains a summary of cost estimates for the proposed improvements in the Cool Creek watershed. Detailed costs estimates can be found in Appendix G. Additional discussion on the proposed improvements follows in Sections 7.4 through 7.7 of this chapter.

Table 7-1
Proposed Improvements Cost Summary

Project Description	***Total Project Cost***
151st Street Roadway Modification	$10,000
171st Street Roadway Modification/Bridge Replacement	$700,000
Gurley Street Bridge Replacement	$280,000
Cherry Street Bridge Replacement	$340,000
Carmel Drive (Hot Lick Creek)	$90,000
Swimming Pool Inundation (Hot Lick Creek)	$10,000
Private Drive Culvert Replacement @ US 31 (Highway Run)	$100,000
US 31 Culvert Replacement (Highway Run)	$700,000
Walter St., Private Drive, Walter Ct. Culvert Replacements (Highway Run)	$200,000
Thornberry Drive Culvert Replacement (Highway Run)	$80,000
SR 32 (Main Street) Culvert Replacement (J.M. Thompson Drain)	$310,000
Streambank Erosion D/S of Stonehedge Drive (Highway Run)	$5,000
Streambank Erosion D/S of Rolling Court (H.G. Kenyon)	$15,000
Streambank Erosion U/S of Confluence with White River	$300,000
Streambank Erosion D/S of Gray Road	$75,000
Streambank Erosion Near Hot Lick Creek Confluence	$125,000
Streambank Erosion U/S of 131st Street	$20,000
Streambank Erosion U/S of Keystone Avenue	$30,000
171st Street Regional Stormwater Detention Pond	$2,600,000
Grassy Branch Road Regional Stormwater Detention Pond	$1,800,000
Anna Kendall In-Line Detention Pond Retrofit	$700,000
TOTAL	**$8,490,000**

7.4 STREAM FLOODING/ROADWAY OVERTOPPING SOLUTIONS

The HEC-RAS backwater analysis confirmed that several roadway crossings within the Cool Creek watershed are either: 1) not adequate to meet current INDOT hydraulic requirements; or 2) creating significant headwater during the 100-year storm, resulting in the flooding of residential structures. These crossings are:

- 151st Street (Cool Creek)
- 171st Street (Cool Creek)
- Cherry Street (Anna Kendall)
- Gurley Street (Anna Kendall)
- W. Jersey (J.M. Thompson)
- SR 32 (Main Street) (J.M. Thompson)
- US 31 and Adjacent Private Crossing (Highway Run)
- Walter Street, Walter Court, and Adjacent Private Crossing (Highway Run)
- Thornberry Drive (Highway Run)

The proposed solutions for each crossing are discussed in detail as follows:

7.4.1 E. 151st Street (Cool Creek)

Under existing conditions, 151st Street would be flooded during significant storm events. As the roadway elevation is low relative to the channel elevation, overtopping occurs during storm events less than the 25-year recurrence interval magnitude. As such, the crossing does not meet current INDOT hydraulic standards.

151st Street Bridge (Cool Creek)

The proposed solution consists of approximately 160 LF of roadway elevation modification. Increasing the roadway to a minimum elevation of 823.50 will provide flooding protection up to the 25-year recurrence interval rainfall event, per INDOT requirements. Figure 7-1 illustrates the proposed extents of the roadway modification **(note: figures are grouped together at the end of this chapter)**. The total estimated project cost for this solution is $10,000.

7.4.2 171st Street (Cool Creek)

Under existing conditions, 171st Street would be flooded during significant storm events. Similar to 151st Street, the roadway elevation is low relative to the channel elevation. However, the bridge opening is small at 171st street, adding to the hydraulic restriction. Overtopping occurs during storm events less than the 25-year recurrence interval magnitude. As such, the crossing does not meet current INDOT hydraulic standards.

171st Street Bridge (Cool Creek)

The proposed solution consists of approximately 320 LF of roadway elevation modification and the removal and replacement of the existing bridge. Bridge replacement is necessary to prevent excessive headwaters resulting from a 100-year storm. Replacing the bridge and raising the roadway elevation will provide flooding protection up to the 25-year recurrence interval rainfall event, per INDOT requirements. Figure 7-2 illustrates the proposed improvements. The total estimated project cost for this solution is $700,000.

7.4.3 Gurley Street (Anna Kendall Drain)

Gurley Street is a minor dead-end public roadway with an average roadway width of 11 feet. The existing bridge consists of wooden abutments, 45-degree wooden wingwalls, steel deck supports and a wooden deck. The bridge is in fair to poor structural condition. Under existing conditions, the Gurley Street crossing would be overtopped during the 50-year and 100-year storm events. The overtopping occurs approximately 75 feet north of the bridge at a vertical sag in the roadway. Our independent calculations indicate that this bridge would also be overtopped during the 25-year storm event. However, as this roadway is minor it likely has an ADT well below 1,000. As such, INDOT standards would specify a 10-year storm be used as the criteria for maximum flow before roadway overtopping.

Given the structural condition of the existing bridge, it is recommended that it be replaced. The proposed solution consists of a new single-span concrete bridge. The new bridge will replace the failing wooden structure and provide additional hydraulic capacity. The proposed bridge, as depicted in Figure 7-3, would provide adequate conveyance for the 10-year storm without roadway overtopping. The total estimated project cost for this solution is $280,000.

Gurley Street (Anna Kendall)

7.4.4 Cherry Street (Anna Kendall Drain)

Cherry Street is a 2-lane local roadway with a rectangular concrete bridge opening. The bridge opening area at Cherry Street is smaller than nearby bridges, including Gurley, Union, and Park Streets. Under existing conditions, the Cherry Street crossing would be overtopped during the 50-year and 100-year storm events. This crossing creates a significant hydraulic restriction in the Anna Kendall Drain, raising the 100-year water surface elevation by approximately three (3) feet. Replacing this bridge would provide significant improvements to the upstream floodplain and would help to lower the 100-year floodplain elevation in the downstream reach of the J.M. Thompson Drain.

Cherry Street (Anna Kendall Drain)

The proposed solution consists of a new single-span concrete bridge. The new bridge will replace the current small opening area and will provide adequate hydraulic capacity at the crossing. The proposed bridge, as depicted in Figure 7-4, would provide adequate conveyance for the 25-year storm without roadway overtopping. Furthermore, the hydraulic grade line would be lowered significantly through this reach of drain, helping to alleviate flooding problems upstream of Cherry Street. The total estimated project cost for this solution is $340,000.

7.4.5 W. Jersey Street and SR 32 (Main Street) (J.M. Thompson Drain)

This crossing is impacted by the backwater effects caused by the Anna Kendall Drain, immediately downstream of W. Jersey Street. The proposed improvements to the Cherry Street will help to lower the 100-year floodplain approximately 0.6 feet near the mouth of the J.M. Thompson Drain. However, this is a low-lying area and would nonetheless be subject to flooding during a 100-year recurrence interval rainfall event.

W. Jersey Street Culvert (J.M. Thompson Drain)

Upstream of Main St. (J.M. Thompson Drain)

Replacing the culvert at W. Jersey Street would not have a significant hydraulic impact, given the high tailwater created by the Anna Kendall Drain. As such, it is recommended that no improvements be made at this location.

The Main Street (SR 32) crossing, immediately upstream (north) of W. Jersey Street, creates a significant hydraulic restriction during the 100-year storm, causing flooding in upstream residential areas. In order to reduce flooding potential upstream of SR 32, it will be necessary to replace the existing CMP arch culvert at Main Street with a 12’ x 8’ box culvert, as illustrated in Figure 7-5. The total estimated construction cost to replace this culvert is $310,000.

7.4.6 US 31 and Adjacent Private Drive (Highway Run)

The US 31 crossing, in the lower reaches of the Highway Run, creates a severe hydraulic restriction. Furthermore, the private drive immediately downstream of US 31 creates an additional hydraulic restriction. The resulting headwaters impact the Walter Street/Walter Court neighborhood, causing widespread flooding during a 100-year storm. As such, it will be necessary to replace both culverts in order to lower the 100-year floodplain to a reasonable level.

US 31 Culvert (Highway Run)

The proposed culvert replacements, as depicted in Figure 7-6, will consist of replacing the twin 5' x 4' box culverts (private crossing) with a 10' x 6' box culvert and adding a 60" RCP culvert next to the existing box culverts under US 31. It was assumed that boring and jacking would be necessary at US 31, given the depth of the culvert and traffic volumes. The culvert replacements will help to relieve flooding potential upstream and will reduce flow velocities downstream of US 31. The total estimated construction cost to replace both culverts is $800,000.

7.4.7 Walter Street, Private Drive, and Walter Court (Highway Run)

Three adjacent stream crossings, beginning at the Walter Drive (downstream) crossing and ending at the Walter Court (upstream) crossing, are overtopped during the 10-year storm. The existing crossings, each consisting of triple CMP arch culverts, are partially filled with sediment and do not provide adequate flow conveyance. Replacing each crossing with a single 12' x 4' box culvert, in conjunction with minor channel reshaping, would provide adequate conveyance for the 10-year storm without roadway overtopping. The proposed impr ovements are illustrated in Figure 7-7. The total estimated construction cost to replace both culverts is $200,000.

Private Drive along Walter Street (Highway Run)

Walter Street (Highway Run)

7.4.8 Thornberry Drive (Highway Run)

The Thornberry Drive culvert does not adequately convey the 10-year recurrence interval rainfall event. This is partially due to the hydraulic restriction created by the Walter Street/Court culverts (described above in Section 7.4.7). Replacing the three culverts as described in Section 7.4.7 and replacing the existing Thornberry Drive culverts with a 11' x 3.5' box culvert (see Figure 7-8) will provide adequate conveyance for the 10-year storm. The total estimated construction cost to replace the Thornberry Drive crossing is $80,000.

Thornberry Drive (Highway Run)

7.5 NEIGHBORHOOD PROBLEM SOLUTIONS

7.5.1 Carmel Drive Overtopping (Hot Lick Creek)

The existing twin 48-inch concrete pipes do not provide adequate conveyance for a 10-year recurrence interval rainfall event. Nearby residential structures would be vulnerable to flood waters resulting from roadway overtopping. As such, it will be necessary to replace the existing culverts such that a 10-year storm flow can be adequately conveyed without roadway overtopping.

Carmel Drive (Hot Lick Creek)

The proposed solution consists of 120 lineal feet of a 4-foot rise by 10-foot span reinforced concrete box culvert with 45-degree wingwalls at each end. This improvement will reduce the 10-year peak water surface elevation at Carmel Street by approximately 0.6 feet, approximately 0.4 feet below the roadway elevation. Peak 10-year flow velocities at the downstream end of the Carmel Drive culvert will be reduced from 9.3 feet per second (fps) to just over 5 fps.

It is also recommended to re-grade approximately 120 lineal feet of the open channel upstream of the Carmel Drive culvert so as to provide additional flow capacity and better erosion protection. This is necessary to curb channel erosion that is beginning to occur in this area. Figure 7-9 illustrates the proposed culvert replacement and channel improvement. The total estimated project cost for this solution is $90,000.

7.5.2 Swimming Pool Inundation (Hot Lick Creek)

The Hot Lick Creek meanders within close proximity to an existing swimming pool in the vicinity of 126th Street and Fairbanks Drive. The channel is currently eroding along a wooden fence located near the swimming pool. However, this erosion is *not* related to the flooding susceptibility of the swimming pool located on this parcel.

It is recommended that approximately 105 lineal feet of the channel be relocated, as shown in Figure 7-10, to direct flow away from the existing residential property. Although this will help to prevent erosion along the existing fence, it will *not* affect the hydraulic capacity of the channel and will *not* prevent occasional flooding of the swimming pool area. Any channel relocation should be performed with careful consideration of existing conditions. The existing slope, cross section, and depth of the relocated channel should match those characteristics of the existing channel. The relocated channel should be immediately restored with vegetation and proper erosion control measures. The total estimated project cost for this solution is $10,000.

The floodplain elevation through this reach of channel can only be manipulated by *extensive* channel improvements. Such improvements would be cost-prohibitive and would provide little other substantial benefits. Therefore, only the channel relocation is recommended.

7.6 STREAMBANK EROSION SOLUTIONS

Seven streambank erosion sites were selected for improvements, based on the criteria described in Section 7.2.1. The proposed improvement sites are described as follows:

- Highway Run — Downstream of Stonehedge Drive
- H.G. Kenyon Drain — Downstream of Rolling Court
- Cool Creek — Upstream of confluence with the White River
- Cool Creek — Downstream of Gray Road (at bend)
- Cool Creek — Upstream and downstream of Hot Lick Creek
- Cool Creek — Upstream of 131st Street (Main Street)
- Cool Creek — Upstream of Keystone Avenue

Proposed solutions range from minor regrading and seeding (for areas experiencing moderate flow velocities) to more intensive improvements such as riprap, geotextile fabric, woody plantings, vegetated geogrids, etc. for areas experiencing high flow velocities or containing steep channel sideslopes. Whenever possible, streambank stabilization should employ vegetative measures, so as to maintain the natural state of the channel corridor and to enhance instream water quality. In some instances of severe erosion, a more structural solution such as gabion baskets or revetment may be a more appropriate solution.

For all of the following improvement recommendations, the descriptions "left bank" and "right bank" reference the channel when looking *downstream*.

The proposed solutions described in this section are preliminary only. Upon choosing specific streambank restoration sites, detailed information will need to be collected and each site will need to be analyzed separately. Detailed information needed for a final design would be as follows:

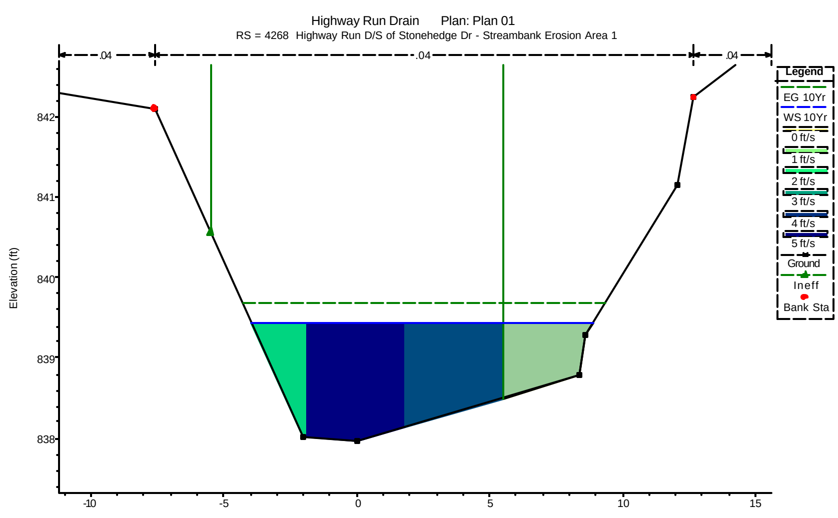
- Channel cross sections at each restoration site, including location of private features, property corners, and nearby utilities.
- Hydraulic analysis for each restoration site, including velocity calculations and shear stress calculations for more frequent (i.e. 1-year, 2-year) recurrence interval rainfall events.
- Soil analysis for each restoration site.
- Determination of land availability (i.e. easements, right-of-way, and land acquisition) for proposed grading.
- Determination of construction access points.
- Public input on proposed improvements (most important when improvements are immediately adjacent to existing homes)

The proposed solutions for each identified erosion area are discussed in detail as follows:

7.6.1 Highway Run: downstream of Stonehedge Drive

Significant streambank erosion is occurring approximately 100 lineal feet downstream of the Stonehedge Drive culvert (see Figure 7-11). Although this erosion area is isolated, it is severe. A utility pole adjacent to the channel is in danger of collapse.

Flow velocities are moderate in this area. The 10-year peak flow velocity, approximately 5 feet per second (fps), will require some vegetation reinforcement but should not require any more intensive improvements. The 10-year flow velocity distribution at this location is illustrated below.



Velocity Distribution: Highway Run downstream of Stonehedge

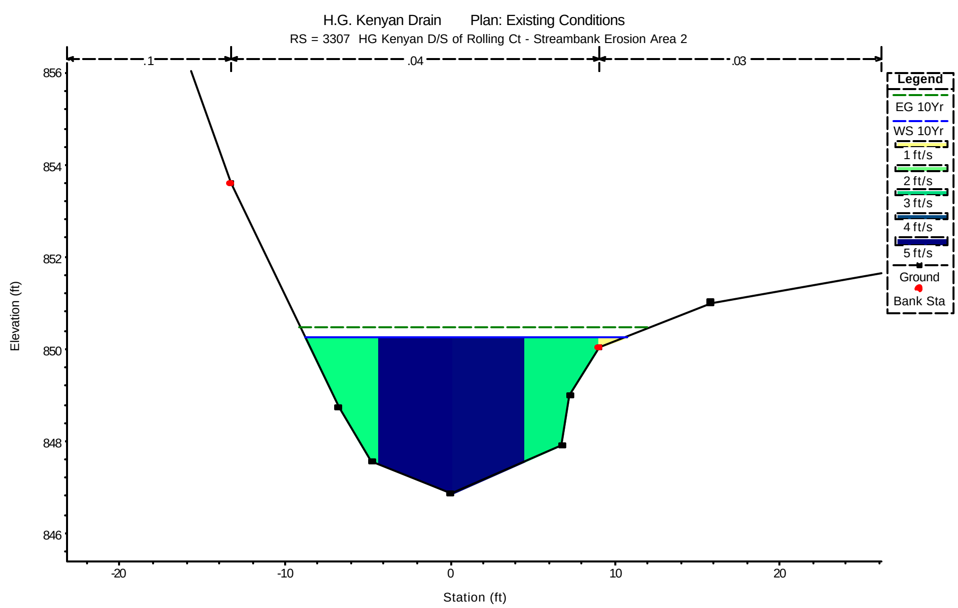
It is recommended that approximately 100 lineal feet of the Highway Run streambank be re-graded to a slope not to exceed 3:1 (horizontal:vertical). This will provide a flatter sideslope and will help to reduce flow velocities. The modified streambank should be reinforced with an erosion matting and grass seed specifically designed for open channels (often referred to as "ditch mix").

Some grading may be required on both sides of the channel in order to accommodate the existing utility pole. Streambank reinforcement should be implemented a minimum of *2 vertical feet* from the channel bottom.

7.6.2 H.G. Kenyon Drain: downstream of Rolling Court

Streambank erosion is occurring downstream of the Rolling Court culvert (see Figure 7-12). This erosion continues around a 90-degree bend in the channel for a total length of approximately 250 lineal feet. Although the majority of the identified erosion is occurring on the right channel bank, there is a steep bank on the left side of the channel that will be vulnerable to considerable erosion if left unchecked.

Flow velocities are moderate in this area. The 10-year peak flow velocity of approximately 5 feet per second (fps), will require some vegetation reinforcement but should not require any intensive improvements. The 10-year flow velocity distribution at this location is illustrated below.



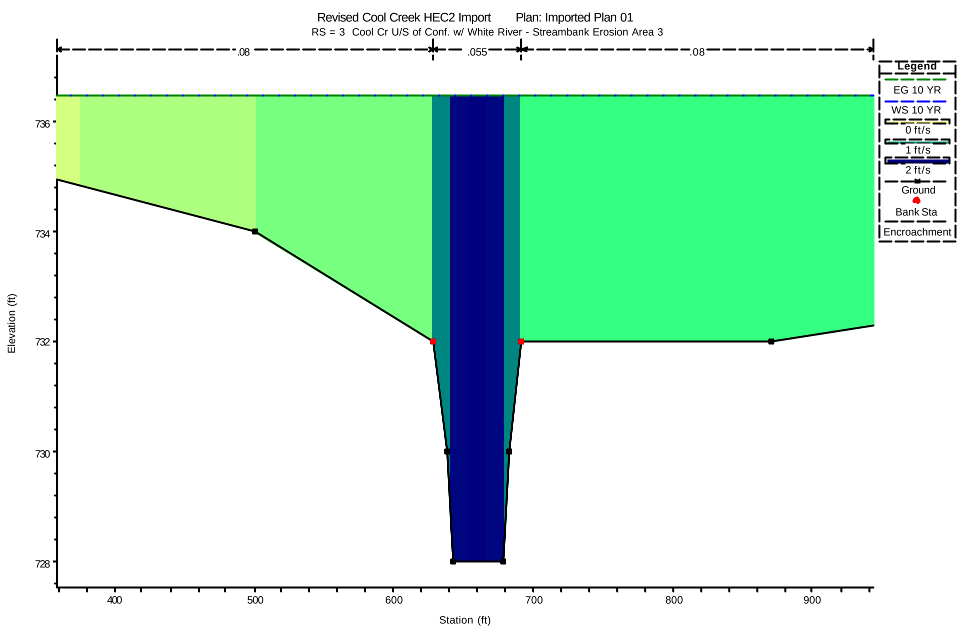
Velocity Distribution: H.G. Kenyon Drain downstream of Rolling Ct.

It is recommended that 250 lineal feet of the Highway Run streambank (right side only) be graded to a slope not exceeding 3:1 (horizontal:vertical) and reinforced with vegetative protection. This will protect the soils and increase the friction coefficient along the streambank, thus helping to reduce flow velocities. The modified streambank should be reinforced with an erosion matting and grass seed specifically designed for open channels (often referred to as "ditch mix"). The proposed improvements for this area are similar to those described in Section 7.6.1. Streambank reinforcement should be implemented a minimum of *3 vertical feet* from the channel bottom.

7.6.3 Cool Creek: upstream of confluence with the White River

Streambank erosion is occurring in the downstream reaches of the Cool Creek, immediately upstream of its confluence with the White River (see Figure 7-13). This erosion occurs over an approximate length of 1500 lineal feet. The erosion in this area is severe, with incised streambanks (near vertical sideslopes) and undercut channels.

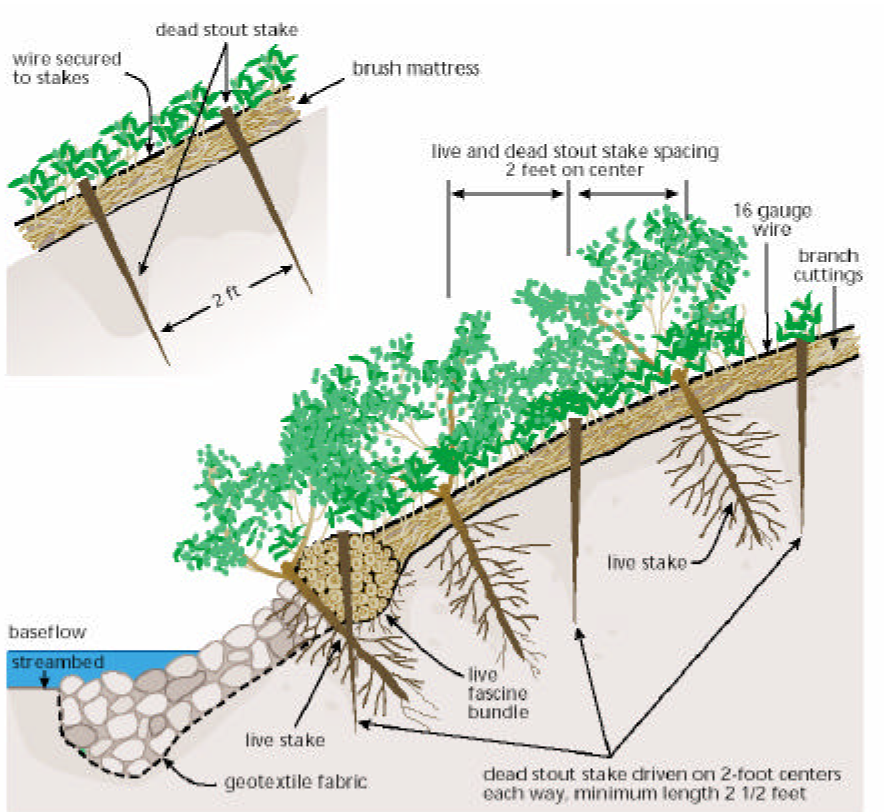
Although the 10-year peak flow velocity is low in this reach, approximately 2 fps, it is likely that more frequent storm events (i.e. 1-year and 2-year recurrence interval) have a significant impact on the channel, as the White River backwater would likely have a smaller impact on the Cool Creek and velocities would be higher. The 10-year flow velocity distribution at this location is illustrated below.



Velocity Distribution: Cool Creek upstream of the White River

Protecting this reach of the Cool Creek is critical, as any erosion in this area would be immediately transported to the White River. Erosion prevention measures at this location should be designed to withstand frequent erosive forces.

It is recommended that 1500 lineal feet of the Cool Creek streambank be re-graded to a slope not exceeding 2:1 (horizontal:vertical) and reinforced using a *brushmattress technique* as illustrated on the following page. This will help to stabilize the streambank from the channel bed to the top of bank with a combination of dense vegetation, geotextile fabric, and riprap. Streambank reinforcement should be implemented a minimum of *4 vertical feet* from the channel bottom. Gabion basket stabilization would also be a viable option at this location.



Brushmattress Technique (Source: USDA-NRCS 1996)

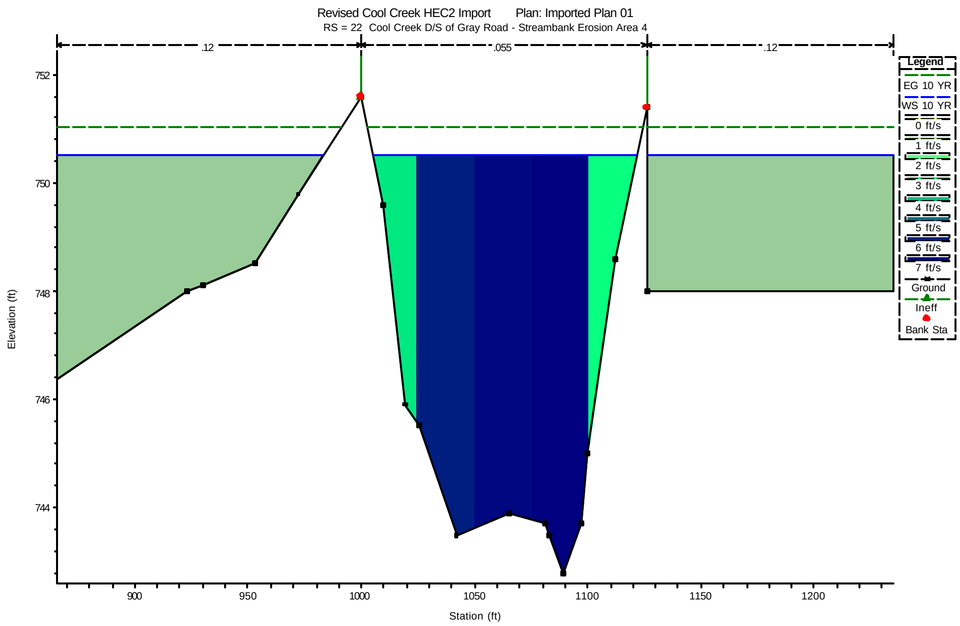
7.6.4 Cool Creek: downstream of Gray Road (at bend)

Streambank erosion is occurring in the Cool Creek downstream of Gray Road (see Figure 7-14). This erosion continues around a sharp bend in the channel for a total length of approximately 200 lineal feet. The streambank along the outside edge of the channel bend is subject to severe erosion. The 10-year peak flow velocities at this location are very high, exceeding 7 fps at the center of the channel. Flow velocities in this range will cause significant erosion in unprotected areas. The 10-year flow velocity distribution at this location is illustrated on the following page.

Protecting this reach of the Cool Creek will require significant protection along the lower portion of the main channel to combat the high flow velocities.

It is recommended that 200 lineal feet of the Cool Creek streambank be reinforced using a *vegetated geogrid* as shown in the illustrations and photographs on the following pages. This will help to stabilize the streambank from the channel bed to the top of bank with a combination of dense vegetation, geotextile fabric, and boulders.

Riprap toe protection should be installed along the toe of streambank to provide additional protection against streambank incision. The riprap toe protection should be provided using brushmattress technique previously discussed. Streambank reinforcement should be implemented a minimum of *6 vertical feet* from the channel bottom.

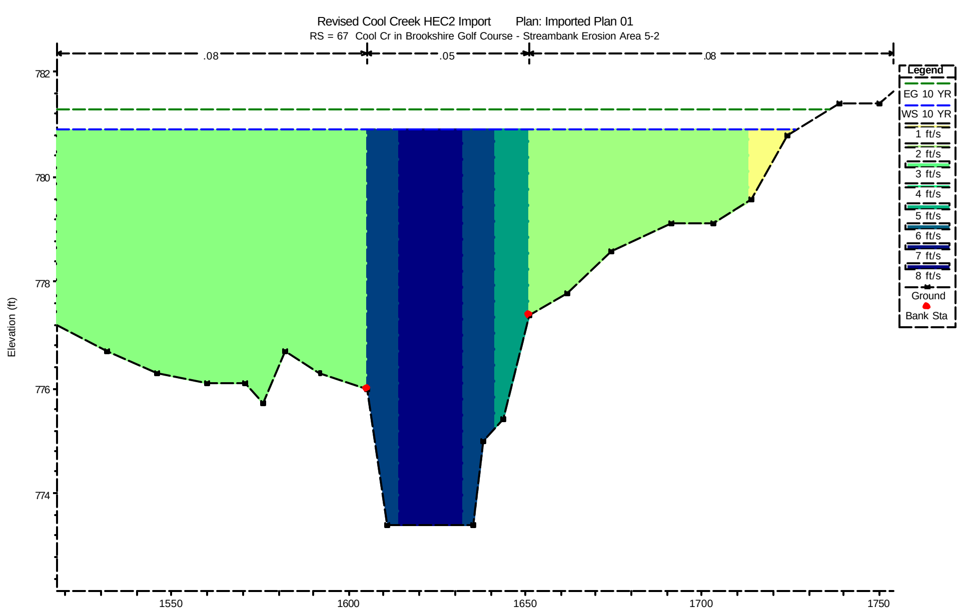


Velocity Distribution: Cool Creek downstream of Gray Road

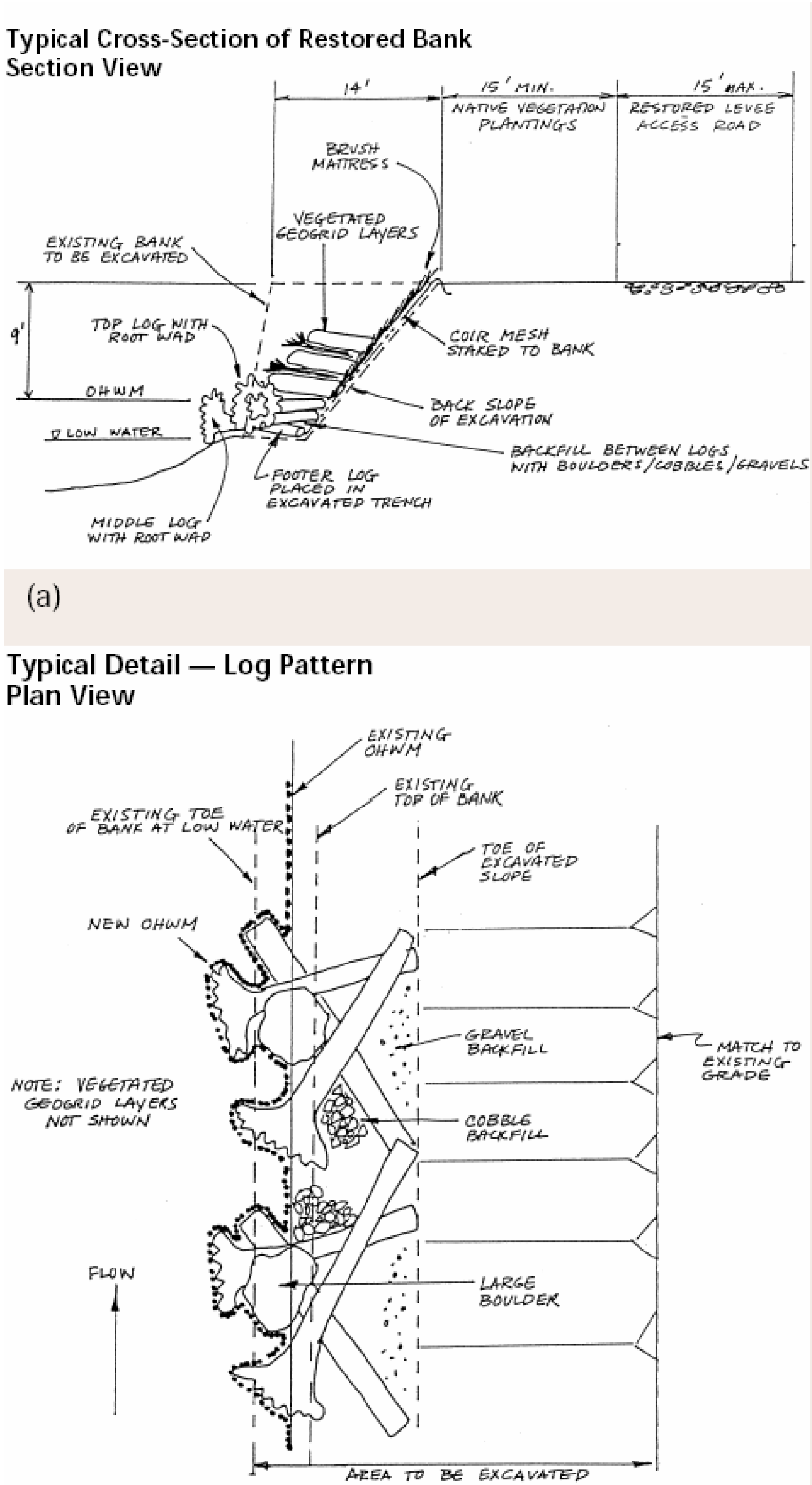
7.6.5 Cool Creek: upstream and downstream of Hot Lick Creek

Streambank erosion is occurring in the Cool Creek in the vicinity of the Hot Lick Creek, through the Brookshire Golf Course (see Figure 7-15). This erosion is severe and will likely continue to worsen unless preventative measures are taken.

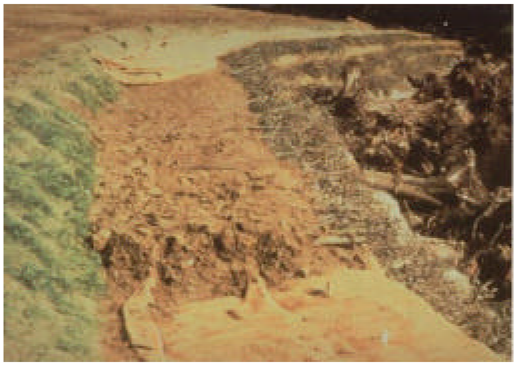
The 10-year peak flow velocities at this location are very high, exceeding 8 fps at the center of the channel. Flow velocities in this range will cause significant erosion in unprotected areas. The 10-year flow velocity distribution at this location is illustrated below.



Velocity Distribution: Cool Creek in vicinity of Hot Lick Creek



Vegetated Geogrid (Source: King County Surface Water Management Division)

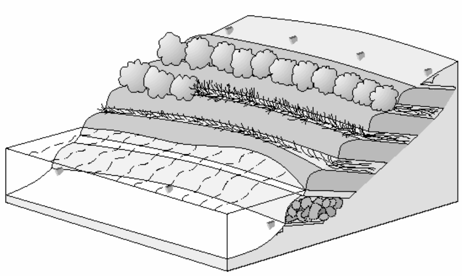


Geogrid Installation

Geogrid Post-Installation

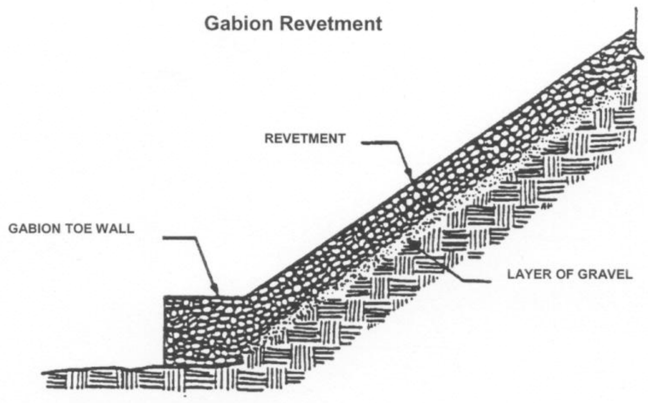
Geogrid after Complete Establishment of Vegetation

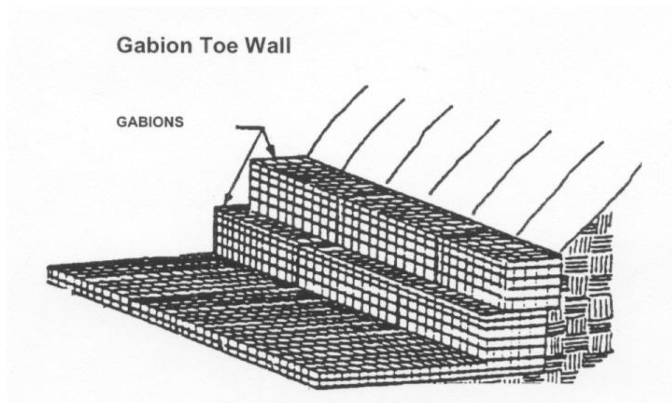
Vegetated Geogrids



Alternating layers of live branch cuttings and compacted soil with natural or synthetic geotextile materials wrapped around each soil lift to rebuild and vegetate eroded streambanks.

Vegetated Geogrids can also consist of branch cuttings and live stakes, as opposed to large diameter tree trunks, as depicted in the photos above. (Source: Federal Interagency Stream Restoration Working Group, 1998)





Source: Chattanooga Public Works Department

Example of Gabion channel bank stabilization on Cool Creek near Underwood Court in City of Carmel

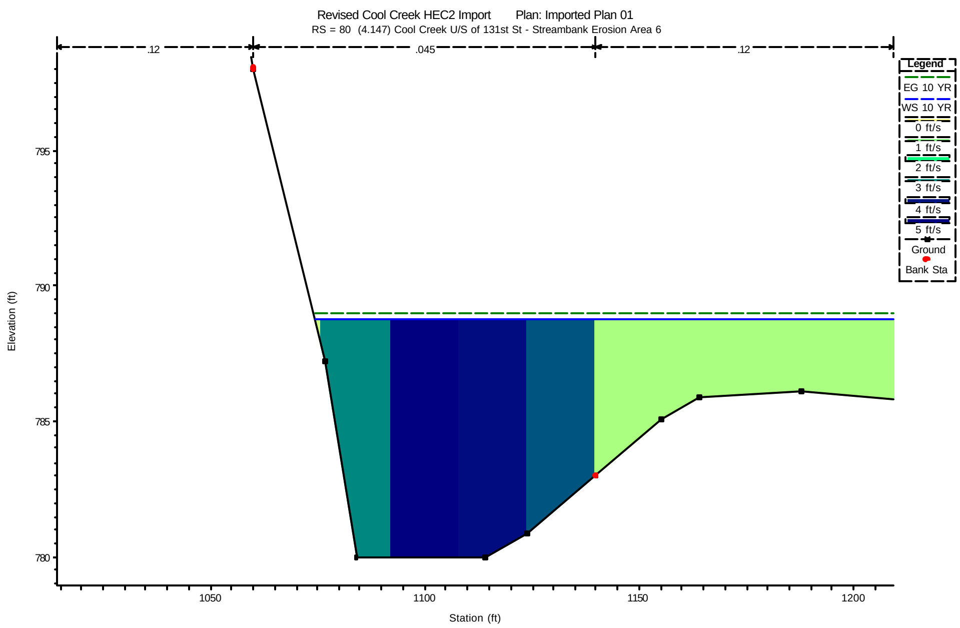
Protecting this reach of the Cool Creek will require significant protection along the lower portion of the main channel to combat the high flow velocities.

It is recommended that a total of 575 lineal feet of the Cool Creek streambank be reinforced using the *brushmattress technique* as described in Section 7.6.3. Streambank reinforcement should be implemented a minimum of *3 vertical feet* from the channel bottom.

7.6.6 Cool Creek: upstream of 131st Street (Main Street)

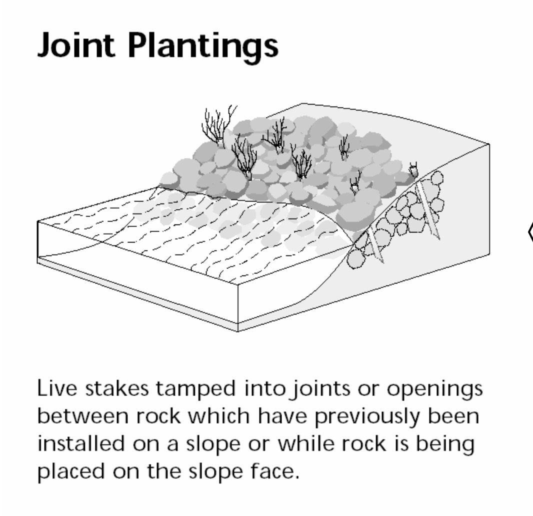
Streambank erosion is occurring in the Cool Creek immediately upstream of 131st Street (see Figure 7-16). This erosion, occurring on 150 lineal feet of the left streambank, is severe and will likely continue to worsen unless preventative measures are taken.

The 10-year peak flow velocities at this location are moderate, exceeding 5 fps at the center of the channel. Flow velocities in this range will cause continued erosion in unprotected areas. The 10-year flow velocity distribution at this location is illustrated below.



Velocity Distribution: Cool Creek upstream of 131st Street

Protecting this reach of the Cool Creek will require some regrading, slope protection, and vegetative reinforcement to protect the channel banks from continued erosion. It is recommended that 150 lineal feet of the Cool Creek streambank be re-graded to a slope not exceeding 3:1 (horizontal:vertical) and reinforced with a combination of riprap (w/geotextile fabric base) and live woody stakes (referred to as the *joint plantings* technique, see illustration on following page). The live stakes will take root along the reinforced streambank and strengthen the channel. Furthermore, the live stakes will grow and shroud the riprap with a natural vegetative cover. Streambank reinforcement should be implemented a minimum of *4 vertical feet* from the channel bottom.

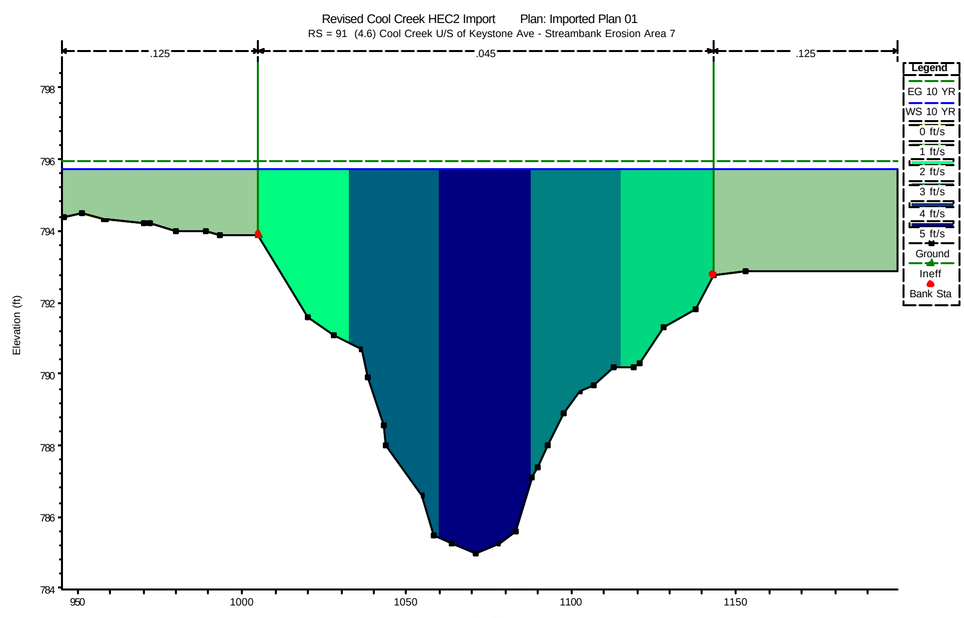


Riprap and Live Stakes (Joint Plantings)
Source: Federal Interagency Stream Restoration Working Group, 1998

7.6.7 Cool Creek: upstream of Keystone Avenue

Streambank erosion is occurring in the Cool Creek immediately upstream of Keystone Avenue (see Figure 7-17). This erosion, occurring on the right channel bank, is severe and will likely continue to worsen unless preventative measures are taken.

The 10-year peak flow velocities at this location are very moderate, exceeding 5 fps at the center of the channel. Flow velocities in this range will cause continued erosion in unprotected areas. The 10-year flow velocity distribution at this location is illustrated below.



Velocity Distribution: Cool Creek upstream of Keystone Avenue

Protecting this reach of the Cool Creek will require some regrading and vegetative reinforcement to protect the channel banks from continued erosion. It is recommended that 100 lineal feet of the Cool Creek streambank be reinforced with a combination of riprap toe protection and a *brushmattress technique* (Section 7.6.3). Streambank reinforcement should be implemented a minimum of *6 vertical feet* from the channel bottom.

7.7 REGIONAL STORMWATER DETENTION

Natural drainage channels are highly sensitive to changes in the magnitude of frequent stormwater runoff (i.e. 1-year and 2-year recurrence interval) events. Urban development, despite the presence of stormwater detention ponds, often increases the magnitude of 1-year and 2-year peak flows. This is a result of a detention pond design focus on the design (i.e. 100-year and 10-year) events. Although detention ponds typically reduce peak flow rates for larger (i.e. 100-year and 10-year) storm events, they often *increase* peak flow rates for more frequent (i.e. 1-year, 2-year) storm events and extend the overall duration of higher flow.

The hydrologic analysis completed for this project showed that major regional detention is not warranted to control the larger storms. Flooding is not a major problem in the lower watershed reaches and the existing detention policy for new development will be effective in controlling peak flows from these larger storms. However, it is recommended that regional detention facilities be constructed in the upper reaches of Cool Creek to help control the magnitude of 1-year and 2-year recurrence interval rainfall events. These facilities should be constructed "off-line" so as to maintain baseflow in the channel, avoid disrupting the existing riparian corridor, and avoid extensive dam safety requirements.

Regional stormwater detention facilities will provide the following benefits to the Cool Creek watershed:

- Reduce peak flow rates for more frequent storms
- Improve water quality by reducing concentrations of sediment, nutrients, and metals
- Increase aquatic habitat by providing wetland and open water areas
- Reduce downstream erosion potential by decreasing the magnitude and duration of the 1-year and 2-year flows, thus further reducing sediment pollution
- Maintain developable land by constructing basins in the existing 100-year floodplain (assuming this land would not be otherwise developable)

Two new regional stormwater detention facilities are recommended. The first is located immediately downstream of 171st Street and the second is located west of Grassy Branch Road. Both detention facilities are located in the upper reaches of the Cool Creek watershed and are within the existing 100-year floodplain.

An existing impoundment created by a culvert under an abandoned railroad embankment is located along the Anna Kendall Drain (immediately upstream of Park Street). This facility is in need of improvements in order to maintain the storage and associated peak flow reductions.

7.7.1 171st Street Off-Line Detention Pond (South Pond)

This detention pond would intercept diverted water immediately south (downstream) of 171st Street. A zero-slope low flow channel would direct the water through in a meandering path towards the pond outlet. Emergent and submergent wetland vegetation should be planted throughout the pond area, creating a means to filter stormwater and remove pollutants prior to discharge back into Cool Creek. The detention pond would discharge into the Cool Creek approximately 1500 channel-feet downstream of 171st Street.

The pond, illustrated in Figure 7-18, would require approximately 160,000 cubic yards of earthwork and would provide approximately 95 acre-feet of stormwater storage. The total estimated project cost for this pond is $2,600,000. Peak flows within Cool Creek could be reduced as follows:

Location	1 Year Storm (cfs)			2 Year Storm (cfs)		
	Existing Flow	Proposed Flow With 171st Street Detention	Percent Reduction	Existing Flow	Proposed Flow With 171st Street Detention	Percent Reduction
171st Street	546	254	53%	699	400	43%
146th Street	883	539	39%	1106	726	34%
131st Street	1107	825	25%	1426	1118	22%
116th Street	1156	944	18%	1497	1267	15%
Confluence	1205	998	17%	1525	1333	13%

The proposed off-line detention basin would provide substantial flow reduction up to the 2-year storm event. Storms exceeding the 2-year magnitude would inundate the detention basin. As the proposed detention ponds are intended to enhance stormwater quality and prevent channel erosion, flow attenuation was not considered for the 10-year through 100-year storm events. Existing detention ponds throughout the watershed provide storage volume for these larger rainfalls.

7.7.2 Grassy Branch Road Off-Line Detention Pond (North Pond)

This detention pond would intercept diverted water from Cool Creek approximately 1,500 feet south of 191st Street and approximately 2,500 feet west of Grassy Branch Road. The general layout and design of this detention pond will be similar to that of the 171st Street Detention Pond. The off-line detention pond would discharge back into the Cool Creek approximately 280 feet west of Grassy Branch Road (approximately 2600 channel-feet downstream of the inlet diversion).

The pond, illustrated in Figure 7-19, would require approximately 100,000 cubic yards of earthwork and will provide approximately 115 acre-feet of stormwater storage. The total estimated project cost for this pond is $1,800,000. Peak flows within Cool Creek could be reduced as follows:

Location	1 Year Storm (cfs)			2 Year Storm (cfs)		
	Existing Flow	Proposed Flow With 186th Street Detention	Percent Reduction	Existing Flow	Proposed Flow With 186th Street Detention	Percent Reduction
171st Street	546	337	65%	699	462	34%
146th Street	883	671	41%	1106	894	19%
131st Street	1107	915	26%	1426	1235	13%
116th Street	1156	989	18%	1497	1347	10%
Confluence	1205	1025	17%	1525	1395	9%

If both the 171st Street and the Grassy Branch Road detention ponds were constructed as recommended in this report, peak flows within Cool Creek would be reduced as follows:

Location	1 Year Storm (cfs)			2 Year Storm (cfs)		
	Existing Flow	Proposed Flow With 171st & 186th Street Detention	Percent Reduction	Existing Flow	Proposed Flow With 171st & 186th Street Detention	Percent Reduction
171st Street	546	192	65%	699	287	59%
146th Street	883	522	41%	1106	696	37%
131st Street	1107	819	26%	1426	1101	23%
116th Street	1156	943	18%	1497	1260	16%
Confluence	1205	998	17%	1525	1327	13%

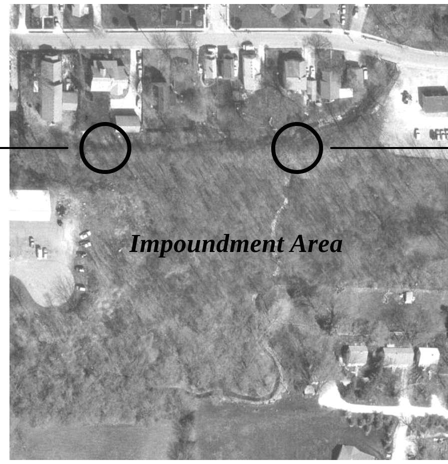
Constructing the proposed off-line detention basins would require the following activities:

- Obtain permanent easements for the pond area
- Develop planting and landscape plan for detention pond
- Remove soil material to create storage area
- Manage excess soil material
- Construct inflow weir to direct flood waters from channel to pond
- Construct discharge structure to direct water back to channel

7.7.3 In-Line Detention Pond (Anna Kendall Drain)

A 48-inch culvert under an abandoned railroad embankment creates a significant impoundment area upstream (south) of Park Street on the Anna Kendall Drain. Although there is significant volume in the impoundment area (approximately 80 acre-ft), an existing breach in the embankment limits the amount of flow that can be stored. In addition, the existing 48-inch culvert is beginning to fail and the embankment above the outlet culvert is eroding. The photographs below on the following page show the location and condition of the existing features of this impoundment.

Location of breach in abandoned railroad embankment



Location of existing 48-inch culvert outlet

Breach in abandoned railroad embankment (note deteriorated CMP, pipe in foreground appears to be a bucket or rubbish container)

Upstream end of existing 48-inch culvert outlet (note pipe section has fallen into creek and embankment is eroding above culvert)

Downstream of 48-inch culvert outlet (note how existing outlet is at a channel bend and is subject to erosion)

Looking at impoundment area from top of abandoned railroad embankment (note area is heavily forested)

The area surrounding the existing impoundment is potentially unsafe given the existing embankment breach and the location/alignment of the 48-inch outlet. Three options are available at this site:

1. Retrofit the existing impoundment structure
2. Remove the impoundment structure
3. Do nothing

Retrofit Existing Impoundment Structure

Retrofitting the existing impoundment area will require the following activities:

- Obtain permanent and construction easements for the pond area
- Investigate existing soil properties along the embankment (i.e. soil borings)
- Modify the primary detention pond outlet to discharge further downstream, past the sharp bend in the existing channel
- Construct an emergency spillway and raise the elevation of the embankment to provide adequate freeboard.
- Repair the existing breach in the embankment and upgrade other portions of the embankment as needed to satisfy IDNR Dam Safety requirements. This may require significant earthwork, up to a complete removal/replacement of the existing embankment.
- Verify that the proposed retrofit does not adversely impact the regulated 100-year floodplain.
- Obtain an IDNR permit for dam improvements.

The final item above would require significant additional expense, due to Indiana Department of Natural Resources (IDNR) requirements for new and retrofitted dams. The IDNR requires that any dam with a drainage area exceeding 1 square mile (Anna Kendall has a drainage area of 2 square miles at the impoundment) meet their design requirements. Meeting the IDNR criteria would require additional engineering/design effort, as well as higher construction costs to install dam safety features.

The proposed pond retrofit would provide approximately 80 acre-feet of stormwater storage. The estimated cost to upgrade the existing impoundment is approximately $700,000.

Retrofitting the detention storage area as described above would have the following effect on peak flows in the Anna Kendall Drain:

Location	2 Year Storm (cfs)			10 Year Storm (cfs)		
	Existing Flow	Proposed Flow With Retrofit	Percent Reduction	Existing Flow	Proposed Flow With Retrofit	Percent Reduction
Downstream of Abandoned Railroad	205	161	21%	380	215	43%

The above peak flow reductions are based on replacement of the existing 48-inch culvert with a similar sized structure. Minor flow reductions (21%) are achieved during the 2-year storm event. It may be possible to have a multi-stage outlet that provides better control flows for the 1- and 2-year storms. During the 10-year event, the impoundment nearly fills and a peak flow reduction of

43% is provided. During a 100-year storm event, the embankment would overtop and peak flow reductions would be negligible. Raising the embankment to contain the 100-year storm volume is not feasible because nearby residential structures would be flooded. IDNR dam safety requirements generally require containment of the 100-year storm. Accordingly, some relaxation in dam safety requirements would be required to make the retrofit a viable option.

Remove Embankment

The second option is to remove a portion of the existing embankment and allow the existing stream to flow unrestricted. This option would resolve the current safety concerns at the site but would also lose the flood control benefits, particularly for the 10-year storm event. The downstream 100-year flood elevations would not be increased because the existing impoundment has negligible 100-year peak flow attenuation. The estimated cost to remove a portion of the existing embankment and return the channel to an unrestricted condition is approximately $100,000.

Do Nothing

The third option, to leave the existing embankment in its current state, is not recommended. Although this involves the lowest initial cost and minimal disruption, it places downstream property owners in a potentially unsafe condition, should the embankment continue to erode and eventually fail.

Evaluation of Options

Removing the existing embankment is the most cost-effective option. However, the flood control benefits provided for the 2- through 10-year storms would be lost. We recommend that the embankment be retrofitted, *provided a compromise can be met regarding IDNR dam safety requirements*. The decision on which option to implement should be made only after the key design issues are discussed with the IDNR and their complete feedback has been received.

7.8 LAND USE AND PLANNING RECOMMENDATIONS

Land use planning and design policies, including design standards, zoning requirements, and site plan review procedures, can be modified to benefit the condition of Cool Creek and its watershed.

7.8.1 Detention Pond Design - Water Quality Volume

Many communities require detention pond designs that incorporate features to help capture pollutants in stormwater runoff. This is generally accomplished by providing a *Water Quality Volume*. The water quality volume is the storage needed to capture and treat runoff from 90% of the average annual rainfall. The *Indianapolis Drainage Design Standards and Specification Manual* (July 2001) contains a requirement for *Water Quality Volume*. This requirement provides for extended detention for the first 1 inch of rainfall. Design standards for reviewing authorities within the Cool Creek watershed should be modified to contain a similar requirement. The *Water Quality Volume* standard will help to control peak flows during more frequent storm events, reduce pollutant loadings to receiving streams, and reduce the potential for downstream channel erosion.

Properly designed and constructed stormwater ponds are generally capable of the following pollutant reductions:

Pollutant	Percent Reduction*
Total Suspended Solids	80%
Total Phosphorus	51%
Ortho-Phosphorus	65%
Total Nitrogen	33%
Nitrate and Nitrite Nitrogen	43%
Copper	57%
Zinc	66%

**Source: National Management Measure Guidance to Control Nonpoint Source Pollution from Urban Areas. U. S. EPA, Draft, July 2002*

Some communities have adopted a *Channel Protection Volume*, which provides additional storage to further reduce the potential for downstream erosion. Maryland has adopted a method that requires holding the runoff volume generated by the 1-year 24-hour duration rainfall (about 2.5 inches in Hamilton County) to be gradually released over a 12- to 24-hour period (Maryland Department of the Environment, Maryland Stormwater Design Manual, Baltimore, Maryland, Volume 1, 2000). The premise of this approach is that runoff will be stored and released so gradually that critical erosive velocities will seldom be exceeded in downstream channels. This approach should be considered given the channel erosion concerns in the watershed.

7.8.2 Stream Buffer Ordinance

Adoption of a Stream Buffer Ordinance would help to prevent development along channel corridors by setting specific limitations on development along natural channels. Often, the protected corridor is 200 to 300 feet wide. A Stream Buffer Ordinance should be adopted to provide the following benefits:

- Natural buffer on each side of channel filters urban runoff prior to discharge into the main channel
- Required setbacks prevent buildings and utilities from being constructed too close to the channel, thereby minimizing property damage due to flooding and erosion
- Promotes green space with multi-use capabilities, such as bike/walk paths, wetland areas, aquatic habitat, etc.
- Mitigates stream warming
- Promotes long-term health of the open channel, minimizing maintenance efforts

The following internet link provides model Stream Buffer Ordinance language that could be adopted, in whole or in part, to protect the Cool Creek and its tributaries.

http://www.stormwatercenter.net/Model%20Ordinances/buffer_model_ordinance.htm

7.8.3 Floodplain Protection

Floodplain development concerns tie directly to preservation of the riparian stream buffers along Cool Creek (and its tributaries). Filling of floodplains can cause loss of flood storage and riparian habitat. As noted previously, Hamilton County has an ordinance that prohibits filling of land in the floodplains of its regulated drains. It may be appropriate for Carmel and Westfield to adopt similar policies for floodplains under their jurisdiction. This would provide a uniform policy and would help preserve existing riparian buffers. Many communities have adopted buffer ordinances to protect headwater streams where floodplains are often narrow and floodplain protection alone may not adequately protect buffer systems.

7.8.4 Other Management Practices

Other recommended management practices concerning development in the Cool Creek watershed (and throughout Hamilton County) include:

- Identifying and protecting critical conservation areas (wetlands, forested areas, floodplains, riparian forest, meadow/prairie areas, etc.)
- Preserving environmentally significant areas (conservation easements, management areas, maintaining native plant species, etc.)
- Promoting urban forestry (decreases runoff, mitigates stream warming)
- Encouraging waterbody and natural drainage protection when siting developments (cluster zoning, other zoning options, urban growth boundaries, etc.)
- Utilizing sound site planning practices
- Utilizing other structural and non-structural Best Management Practices as appropriate, (e.g. porous pavement, sand filters, infiltration practices, water quality swales, manufactured BMPs, vegetated filter strips, bioretention areas, etc.)

The above issues will need to be considered for all urbanized areas of the County as part of stormwater quality regulations promulgated by IDEM (Rule 13).

7.9 SUMMARY OF IMPROVEMENT NEEDS

The following is a summary of the recommended solutions to problem areas in the Cool Creek watershed.

7.9.1 Stream Flooding/Roadway Overtopping Solutions

- E. 151st Street (Cool Creek) – Modify approximately 160 LF of roadway elevation ($10,000)
- E. 171st Street (Cool Creek) – Modify 320 LF of roadway elevation and replace existing bridge ($700,000)
- Gurley Street (Anna Kendall Drain) – Replace existing bridge ($280,000)
- Cherry Street (Anna Kendall Drain) – Replace existing bridge ($340,000)
- SR 32 (Main Street) (J. M. Thompson Drain) – Replace existing culvert ($310,000)
- US 31 and Adjacent Private Drive (Highway Run) – Culvert replacement/addition ($800,000)
- Walter Street, Private Drive, and Walter Court (Highway Run) – Replace three (3) existing culverts and reshape channel ($200,000)
- Thornberry Drive (Highway Run) – Replace existing culvert ($80,000)

7.9.2 Neighborhood Solutions

- Carmel Drive (Hot Lick Creek) – Replace existing twin culverts with new box culvert and install erosion control measures along creek upstream of Carmel Drive ($90,000)
- Hot Lick Creek Channel Improvement – Re-grade existing channel away from nearby residential structure ($10,000)

7.9.3 Streambank Erosion Solutions

- Highway Run, downstream of Stonehedge Drive – Re-grade approximately 100 LF of streambank, reinforce with erosion matting and vegetation ($5,000)
- H. G. Kenyon Drain, downstream of Rolling Court – Re-grade approximately 250 LF of streambank, reinforce with erosion matting and vegetation ($15,000)
- Cool Creek, upstream of confluence with the White River – Re-grade approximately 1500 LF of Cool Creek streambank, reinforce using brushmattress technique ($300,000)
- Cool Creek, downstream of Gray Road – Reinforce 200 LF of streambank using vegetated geogrid and riprap toe protection ($75,000)
- Cool Creek, upstream and downstream of Hot Lick Creek – Reinforce 575 LF of streambank using brushmattress technique ($125,000)
- Cool Creek, upstream of 131st Street – Re-grade approximately 150 LF of Cool Creek streambank and reinforce with combination of riprap and live woody stakes ($20,000)
- Cool Creek, upstream of Keystone Avenue – Re-grade approximately 100 LF of streambank using a combination of riprap toe protection and brushmattress technique ($30,000)

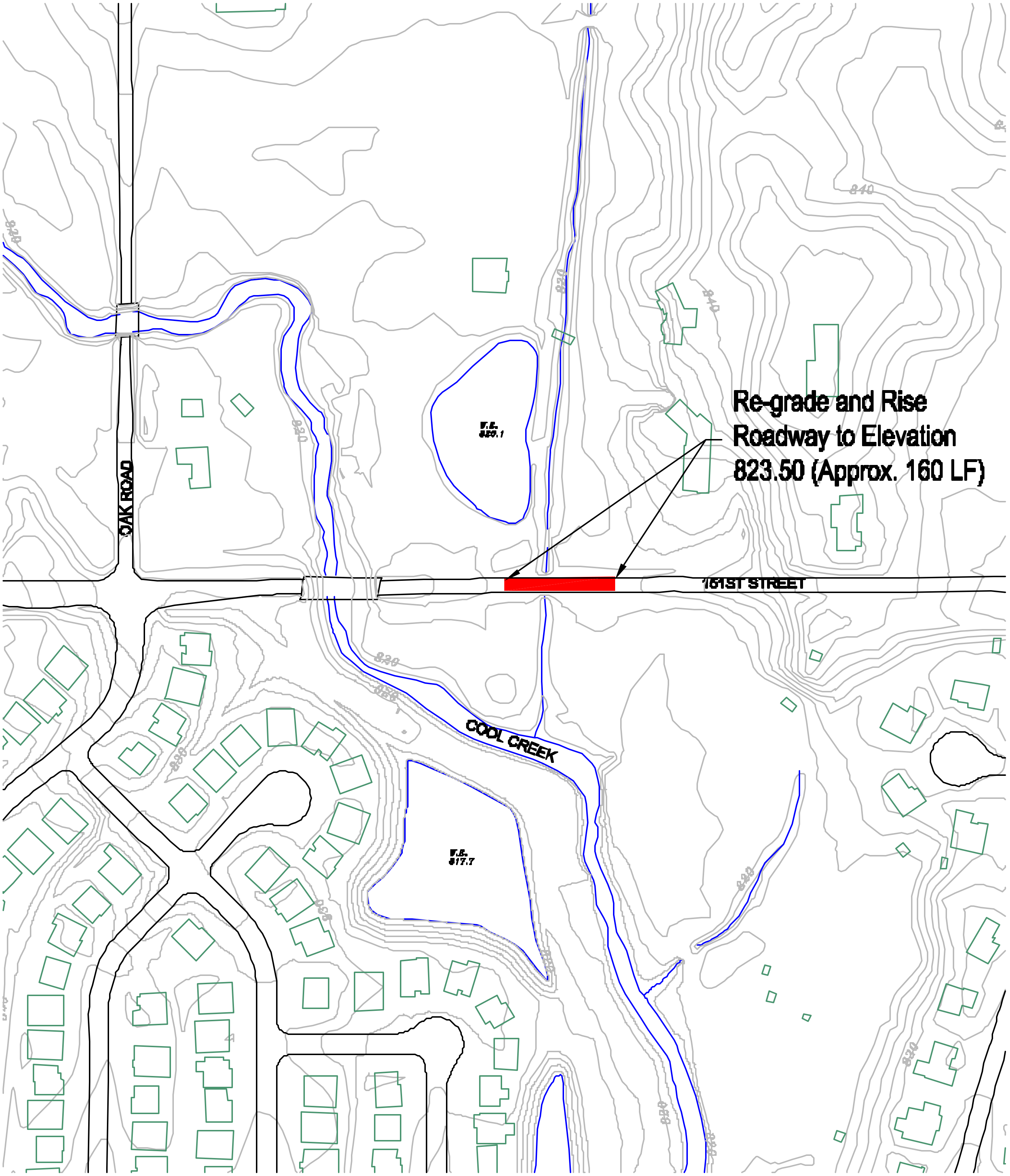
7.9.4 Regional Stormwater Detention Solutions

- 171st Street Off-Line Detention Pond – construct a 95 acre-ft detention basin with a 1800 foot long meandering low flow channel and emergent and submergent wetland vegetation planted throughout the pond area ($2,600,000)
- Grassy Branch Road Off-Line Detention Pond – construct a 115 acre-ft detention basin with a 2600 foot long meandering low flow channel and emergent and submergent wetland vegetation planted throughout the pond area ($1,800,000)
- Anna Kendall In-Line Detention Pond – repair breach in existing embankment, upgrade embankment, and install new control structure and emergency spillway to provide approximately 80 acre-feet of flood storage ($700,000)

7.9.5 Improvements Cost Summary

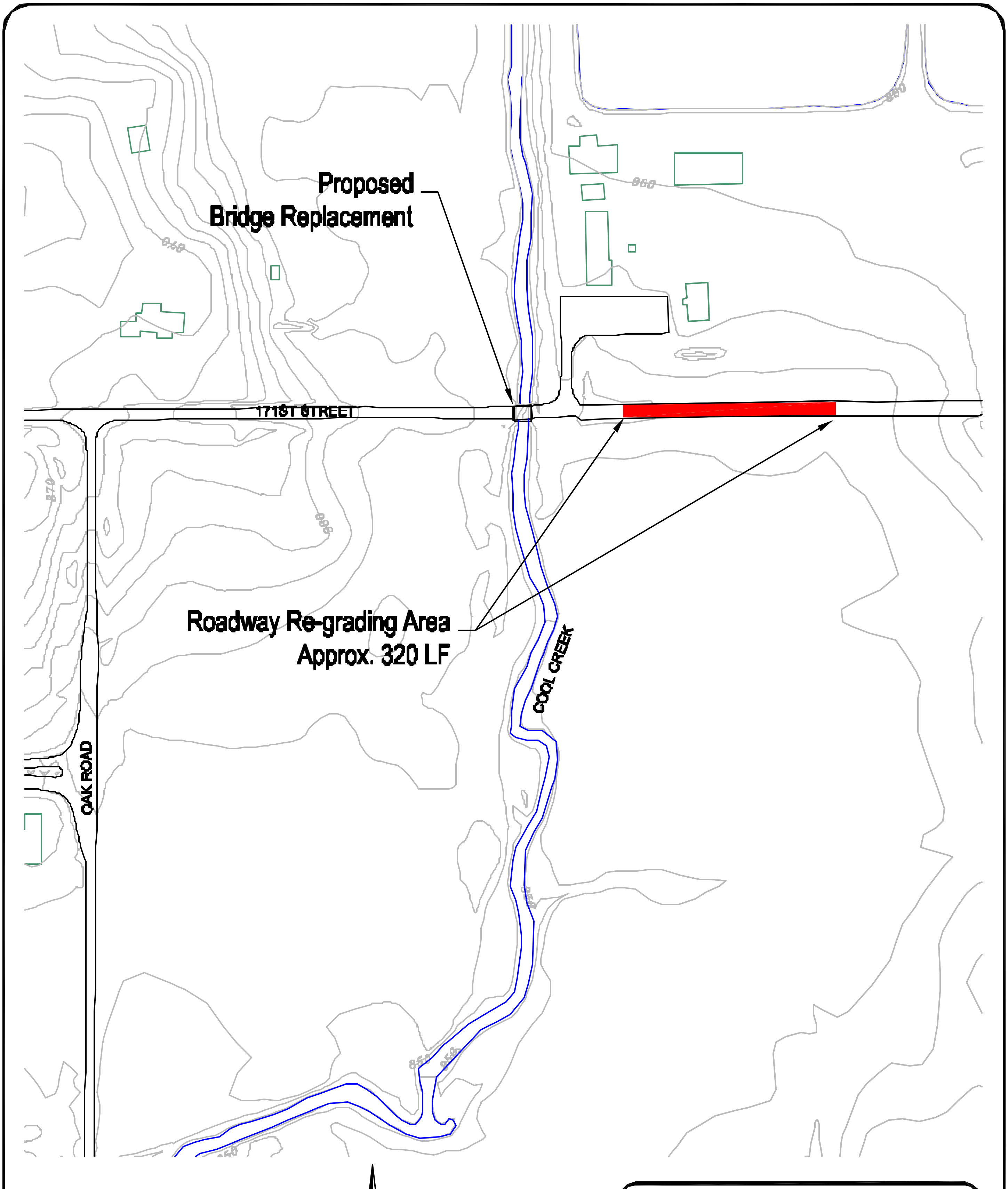
The costs of the proposed improvements are summarized as follows:

Stream Flooding/Roadway Overtopping Solutions	$2,720,000
Neighborhood Solutions	$100,000
Streambank Erosion Solutions	$570,000
Regional Detention Solutions	$5,100,000
Total of All Proposed Solutions	**$8,490,000**



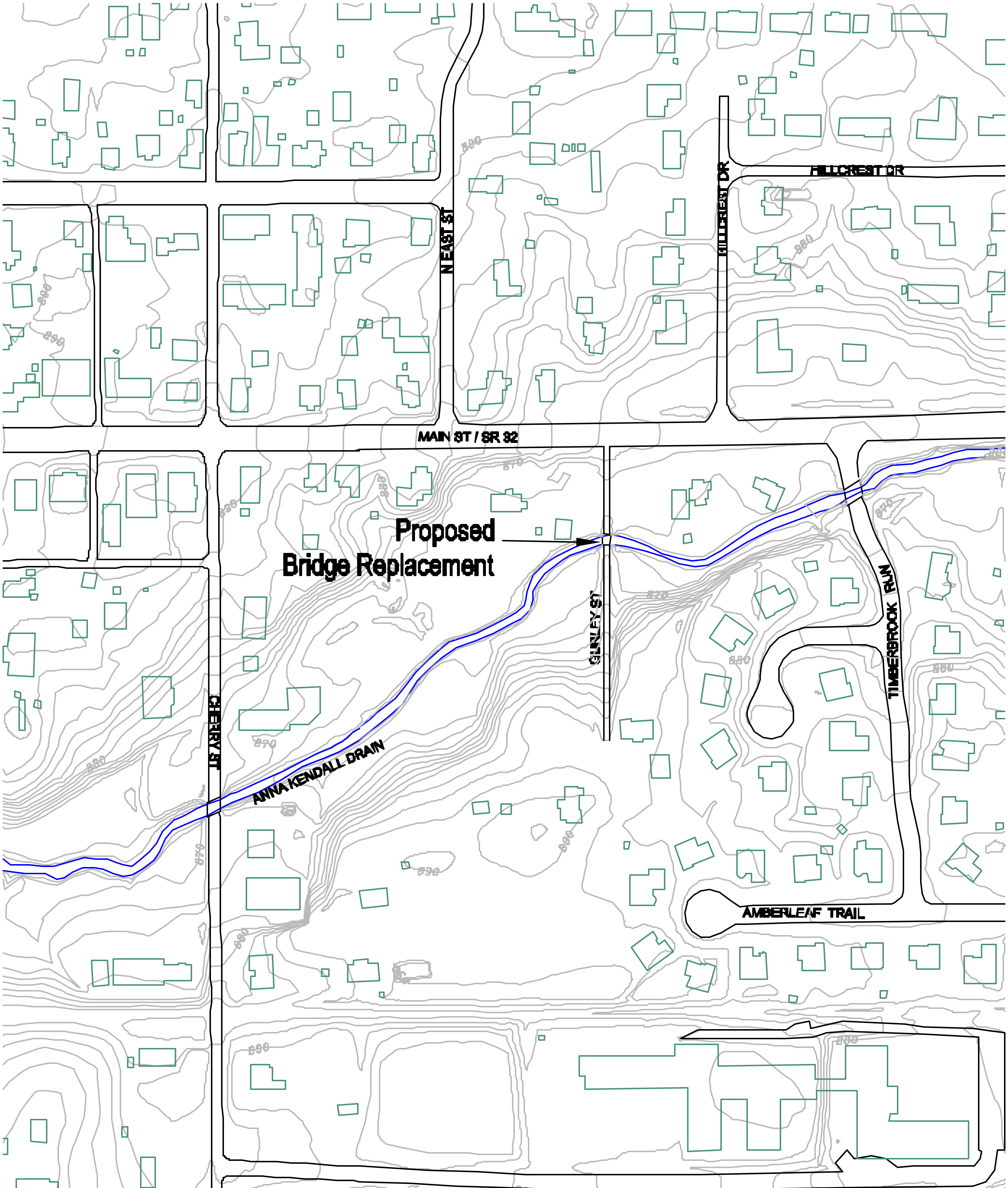
COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-1
151st Street
Stream Flooding/Roadway Overtopping



COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-2
171st Street
Stream Flooding/Roadway Overtopping

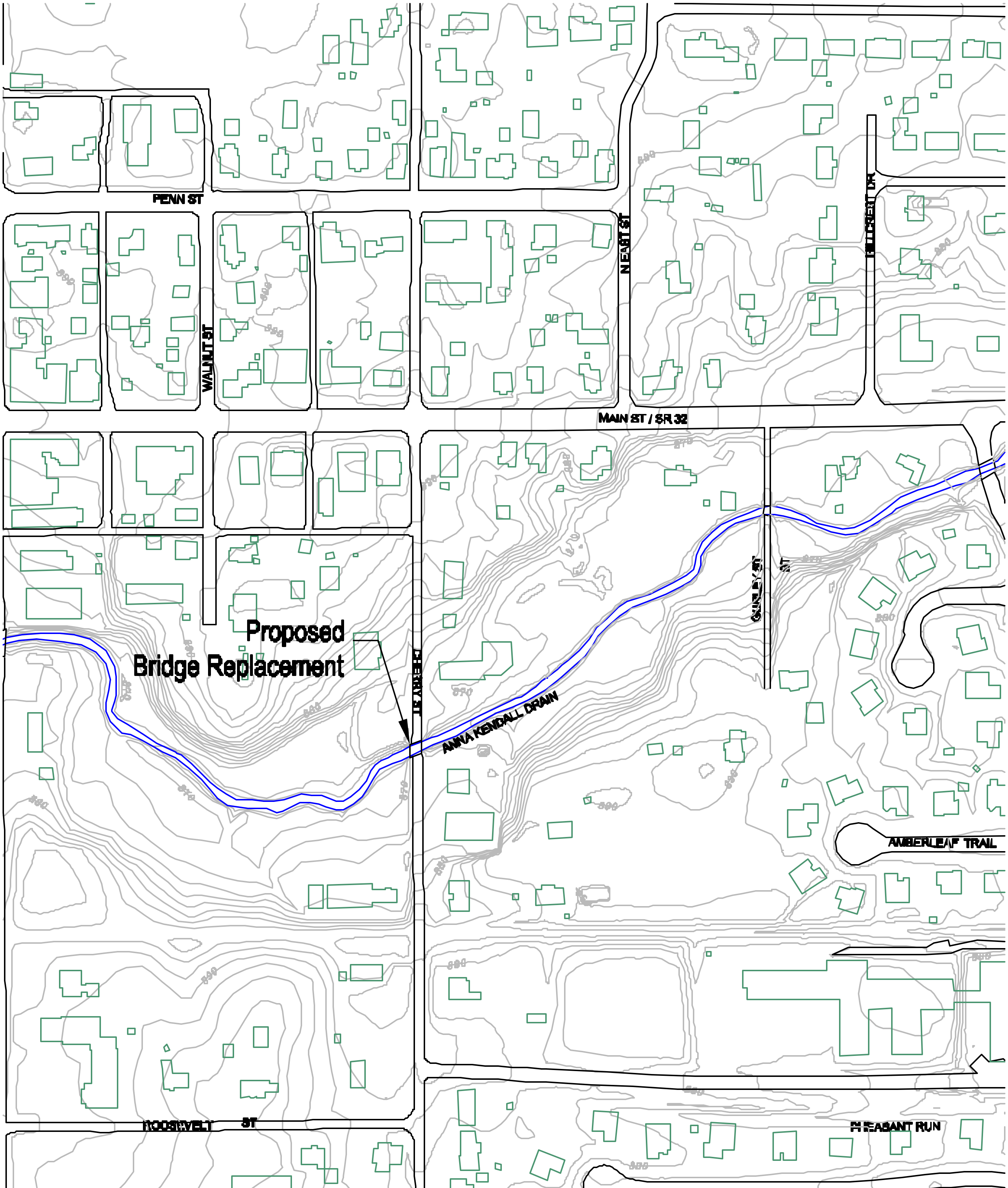


Scale: 1" = 200'

Clark Dietz

COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-3
Gurley Street
Proposed Bridge Replacement



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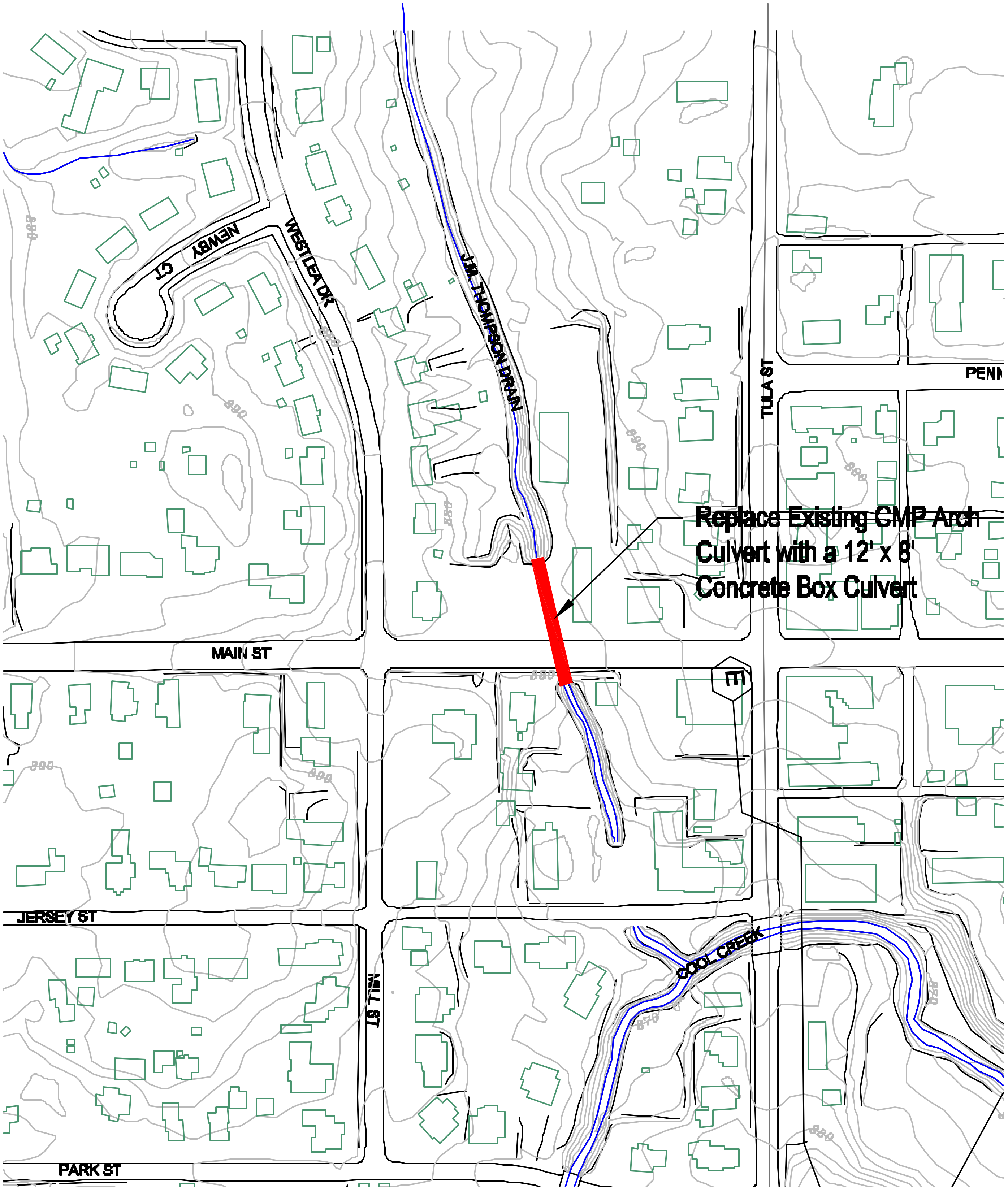
COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-4
Cherry Street
Proposed Bridge Replacement



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COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-5
Main Steet (J.M. Thompson Drain)
Culvert Replacement

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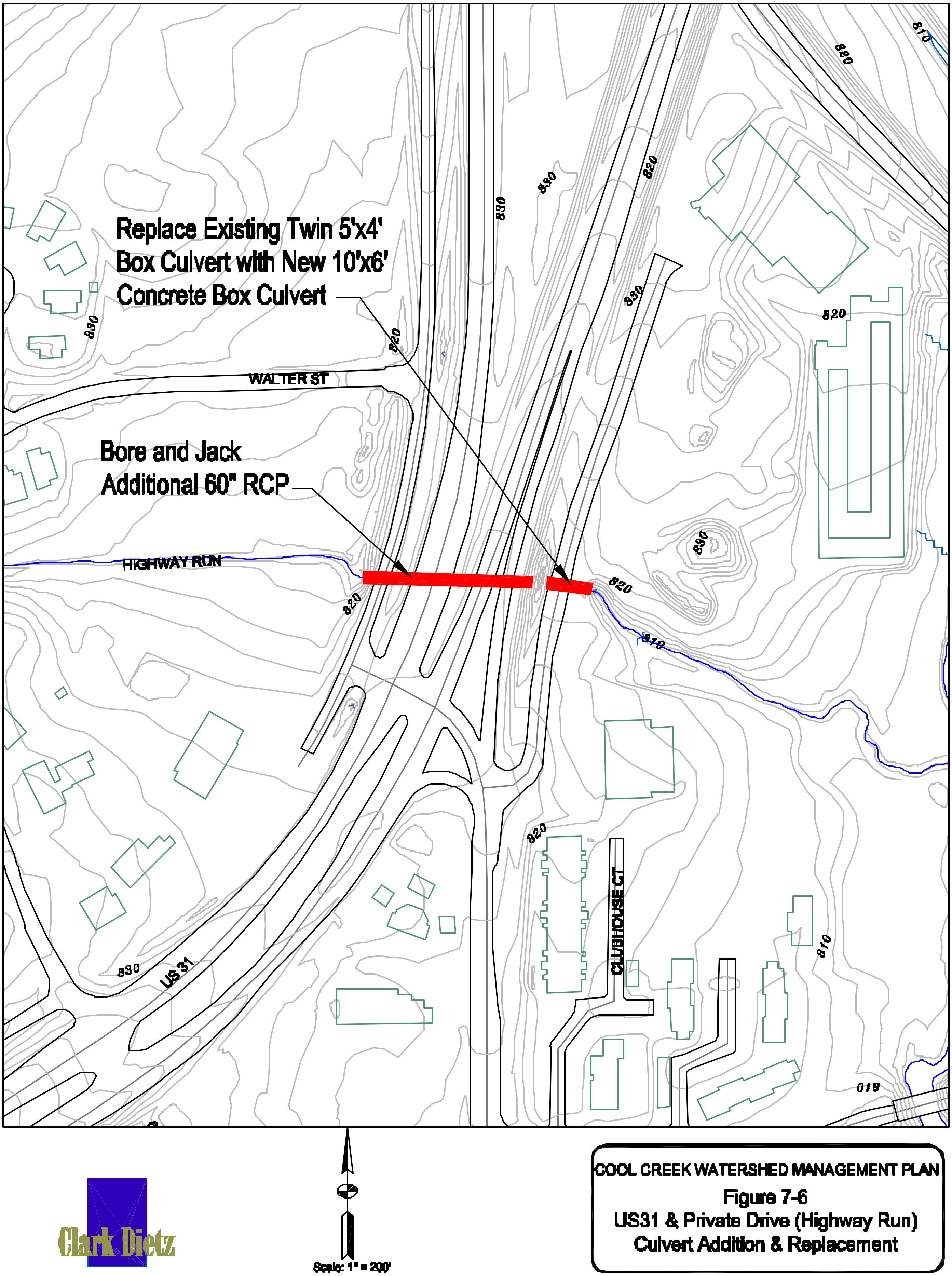

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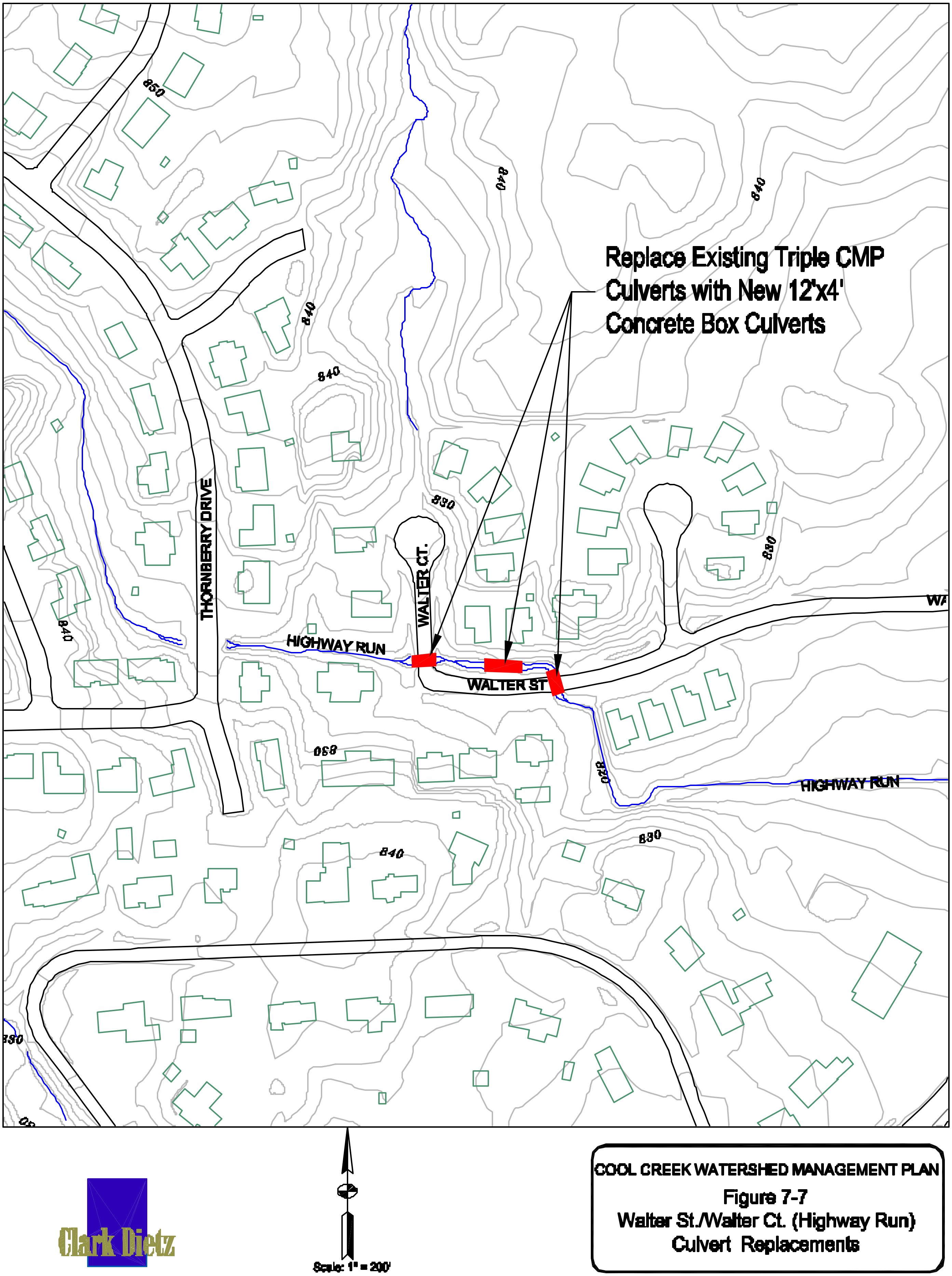
COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-6

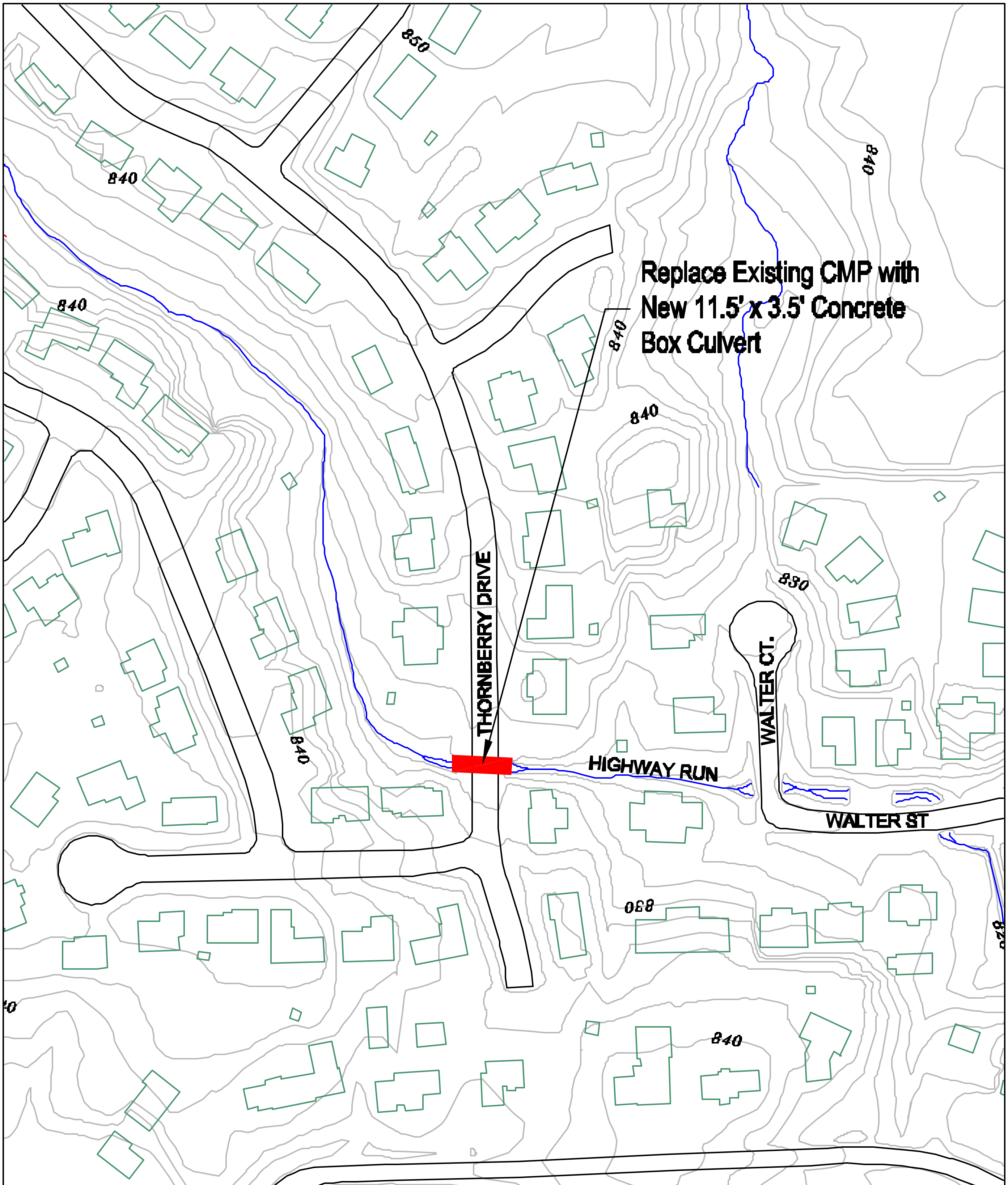
US31 & Private Drive (Highway Run)

Culvert Addition & Replacement



COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-7
Walter St./Walter Ct. (Highway Run)
Culvert Replacements



Scale: 1" = 200'

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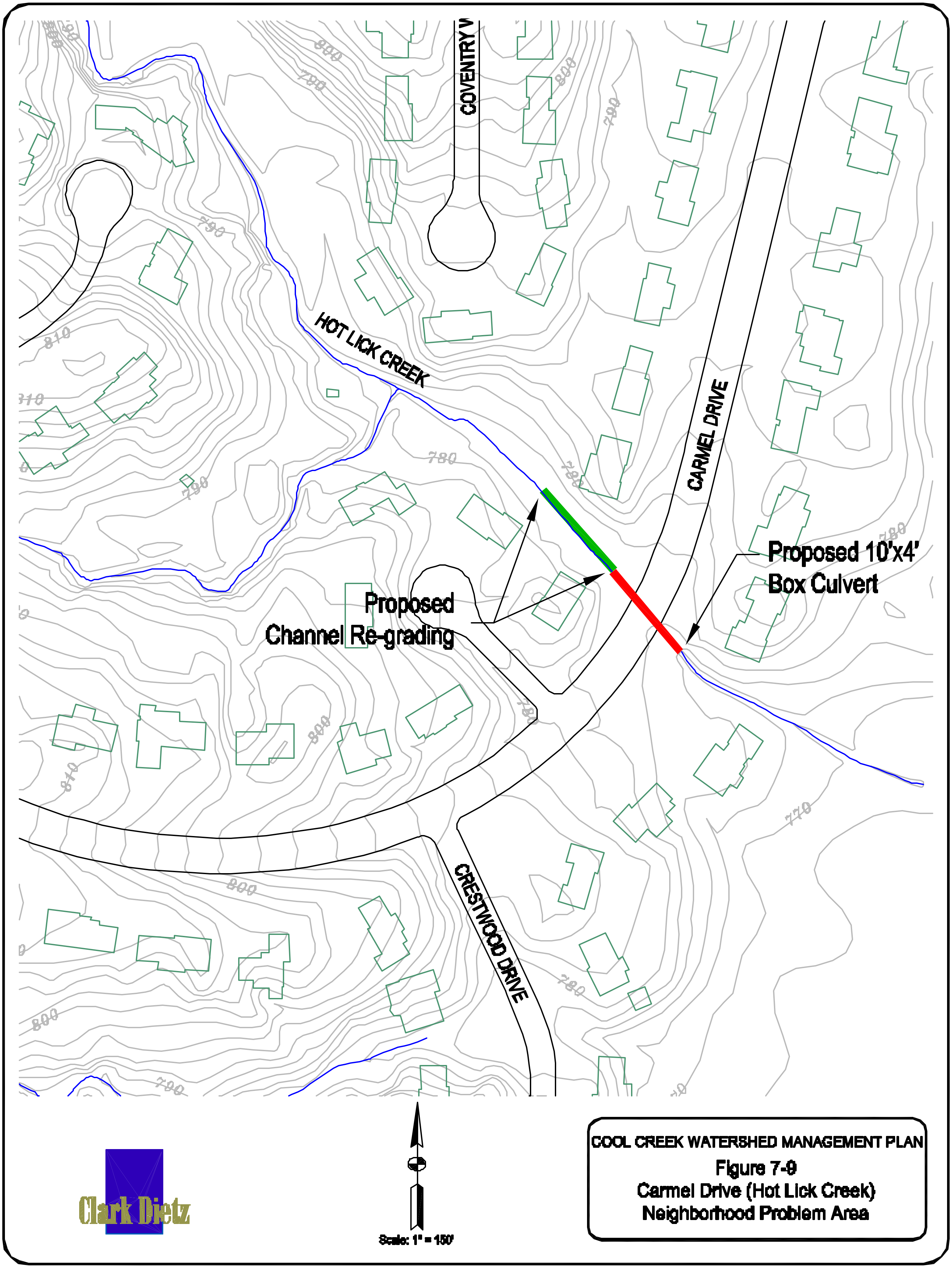
COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-8
Thornberry Drive (Highway Run)
Culvert Replacement

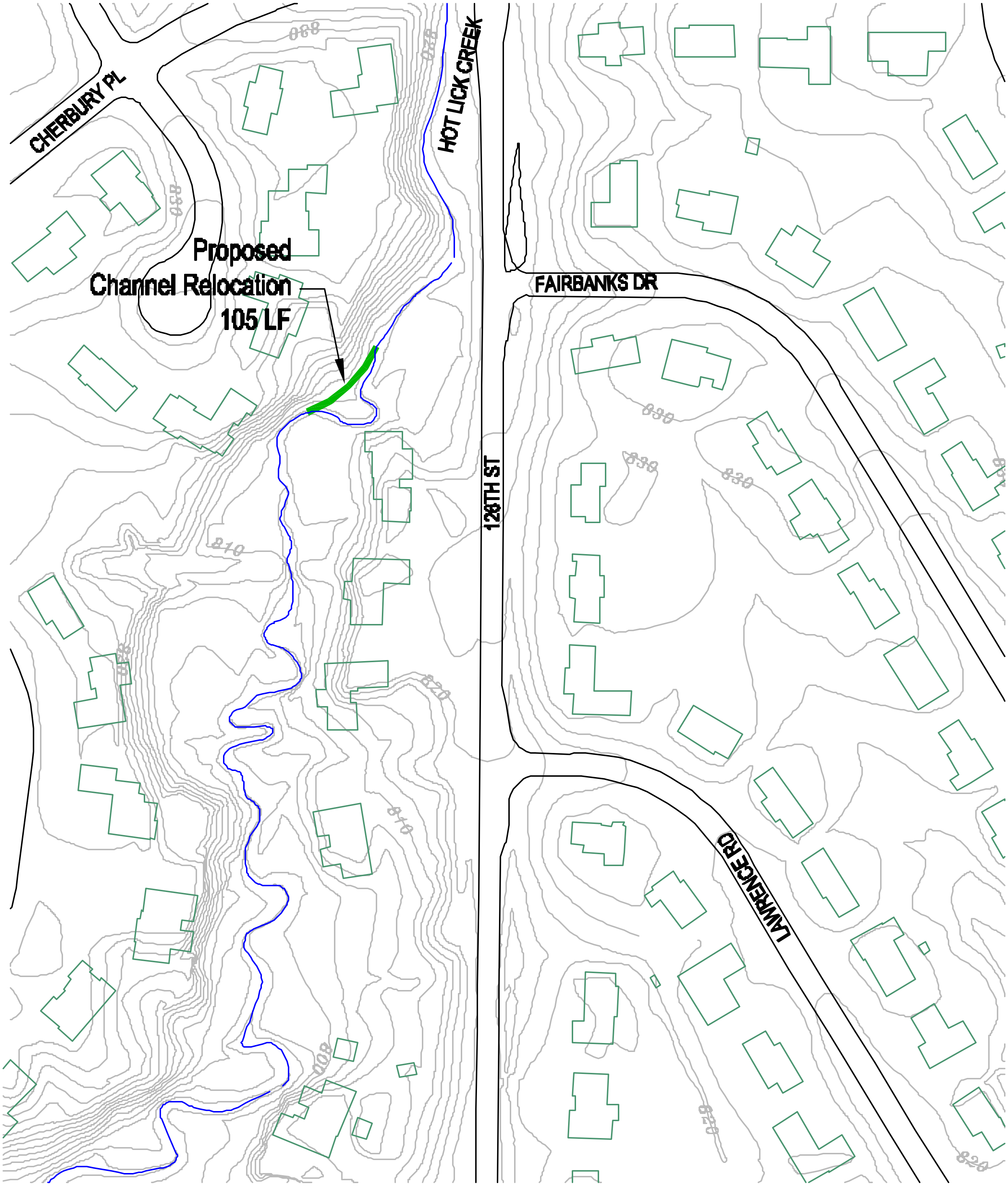


COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-9

Carmel Drive (Hot Lick Creek)

Neighborhood Problem Area



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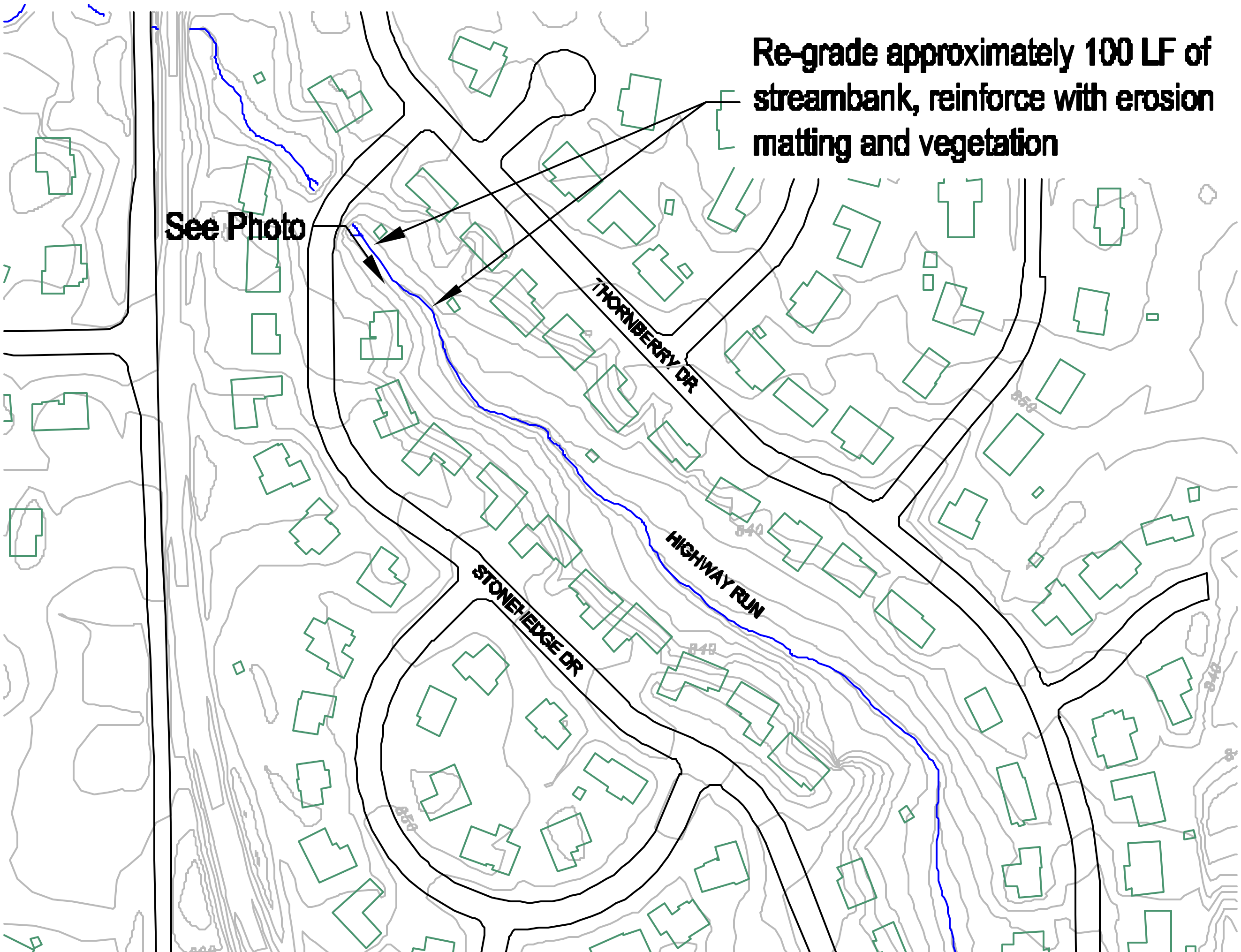
COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-10
Hot Lick Creek Channel Improvement
Neighborhood Problem Area



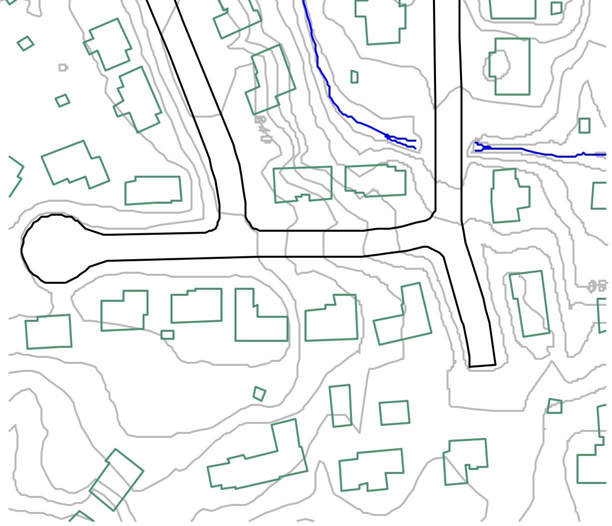
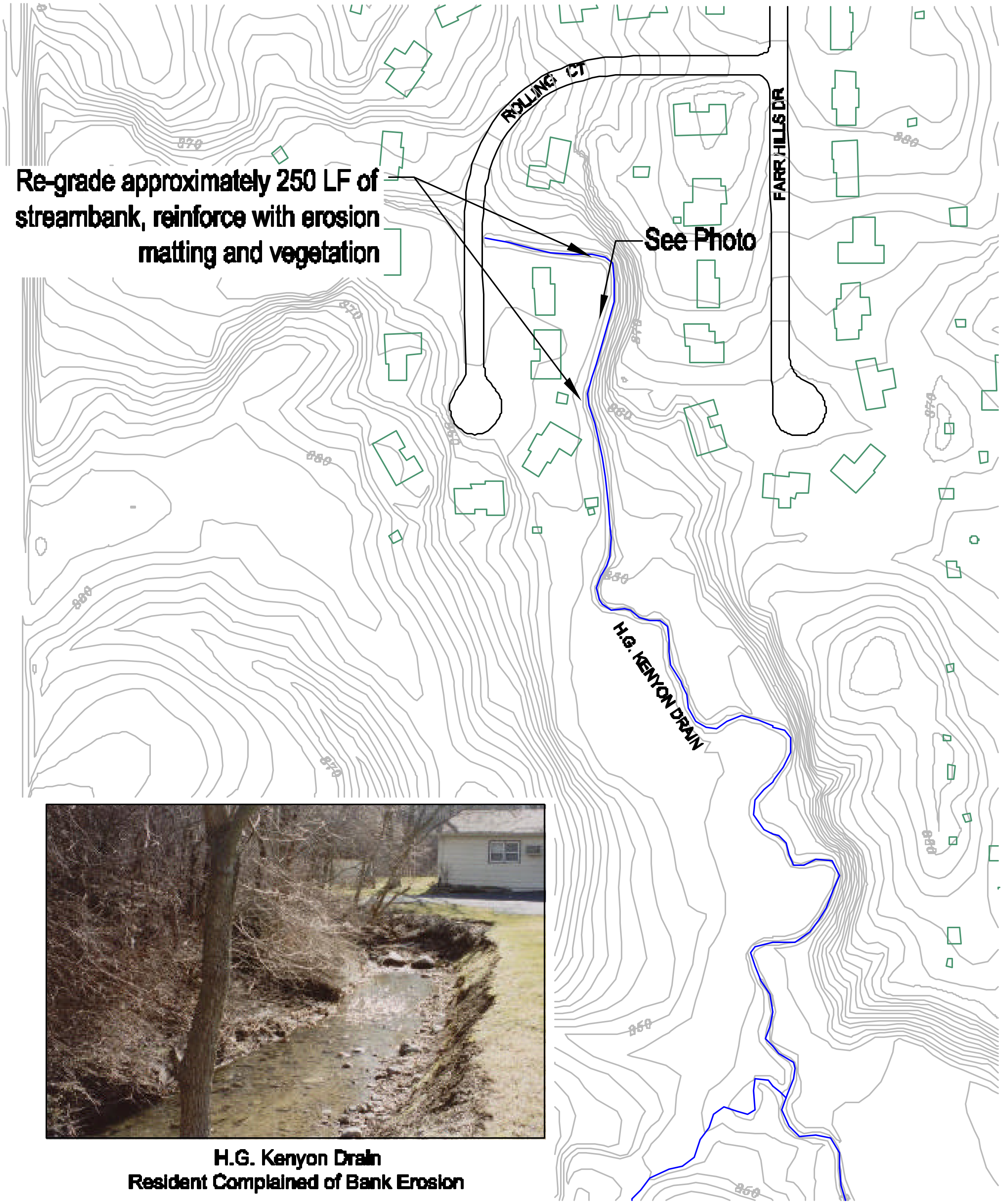


Photo #34 - Highway Run Drain
Trees Undercut by Bank Erosion

Scale: 1" = 200'

COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-11
Highway Run
D/S of Stonehedge Drive



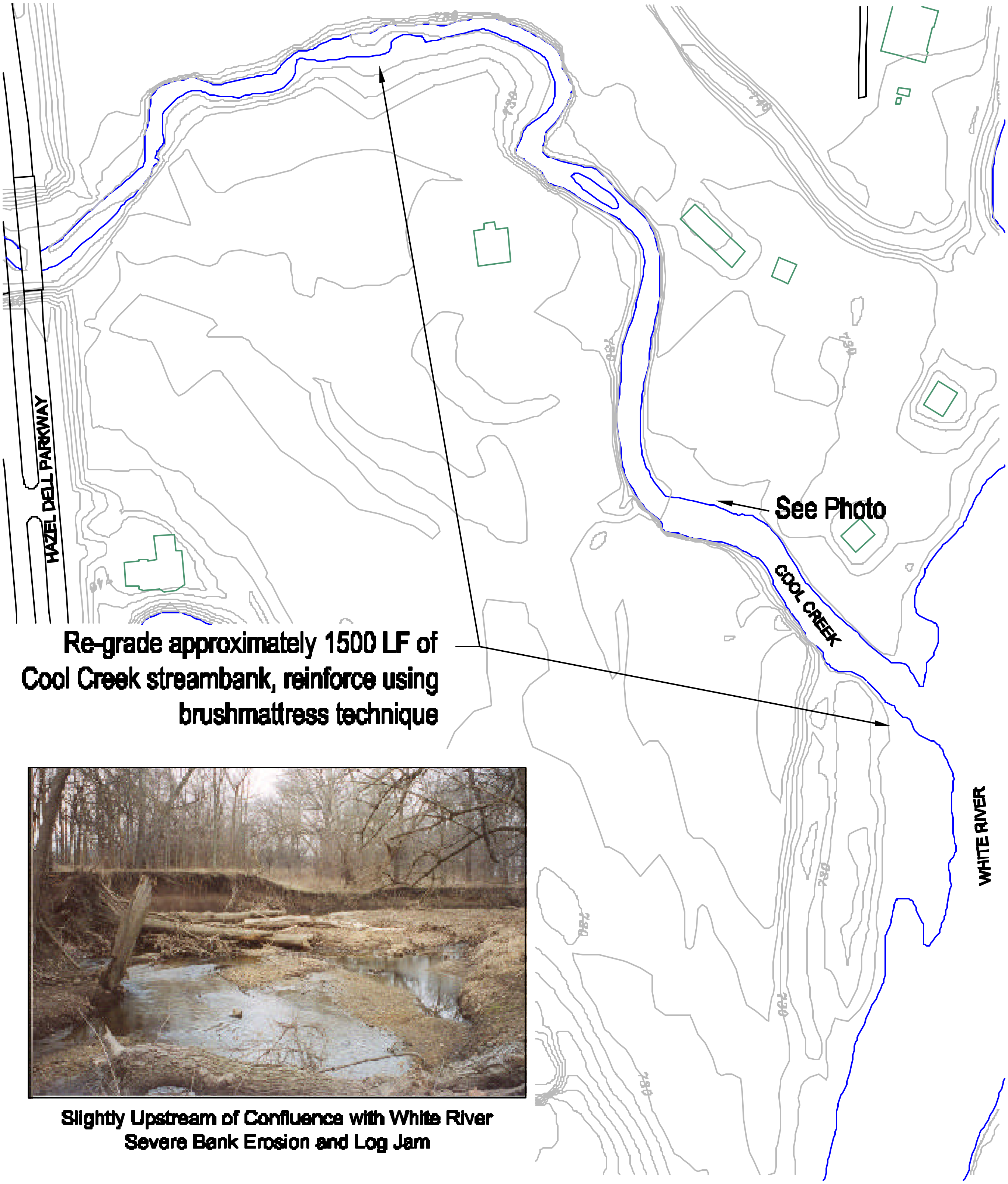
H.G. Kenyon Drain
Resident Complained of Bank Erosion

Clark Dietz

Scale: 1" = 200'

COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-12
H.G. Kenyon Drain
U/S of Rolling Court



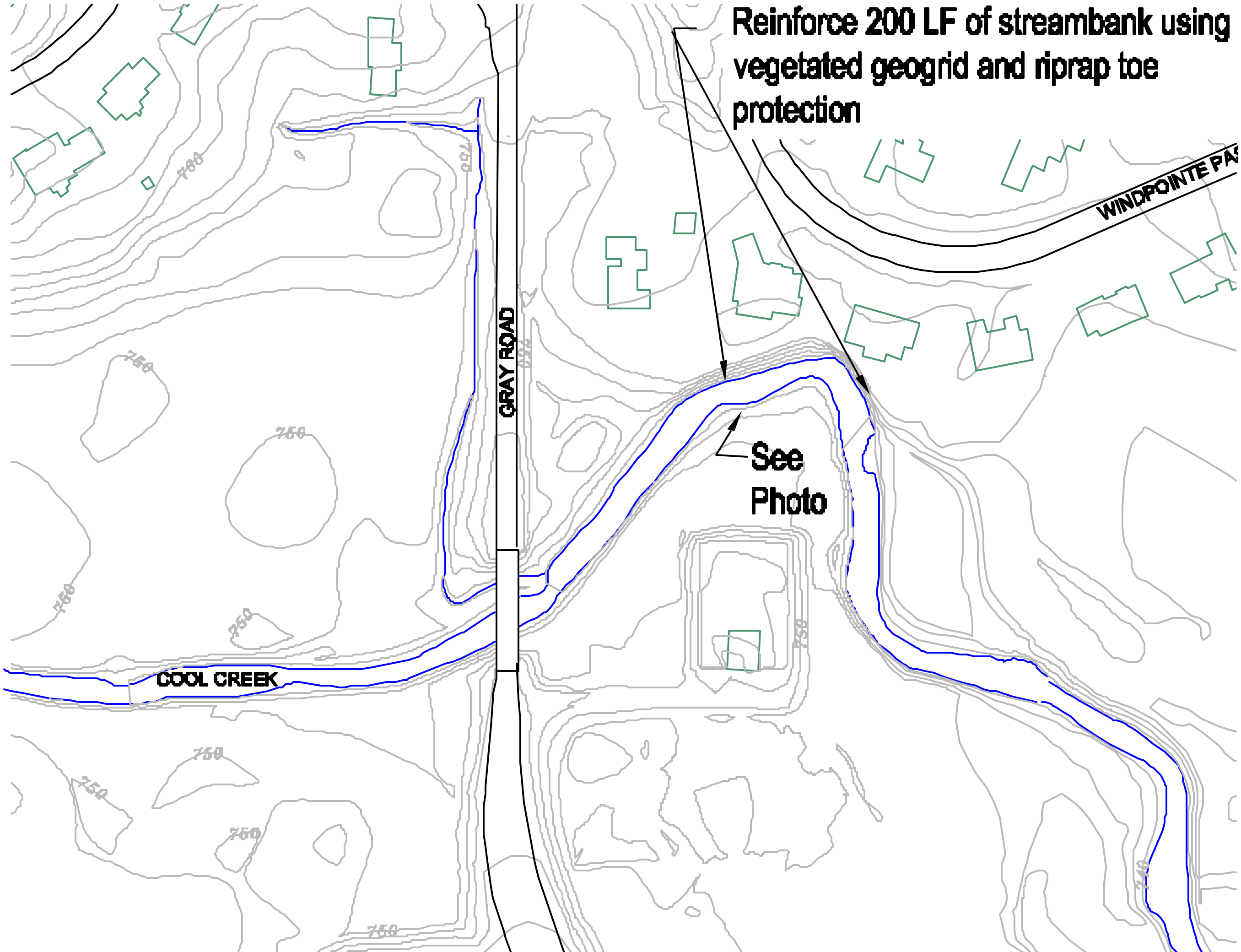
Slightly Upstream of Confluence with White River
Severe Bank Erosion and Log Jam

Clark Dietz

Scale: 1" = 200'

COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-13
Cool Creek
U/S of White River Confluence



Cool Creek
Severe Bank Erosion and Log Jam

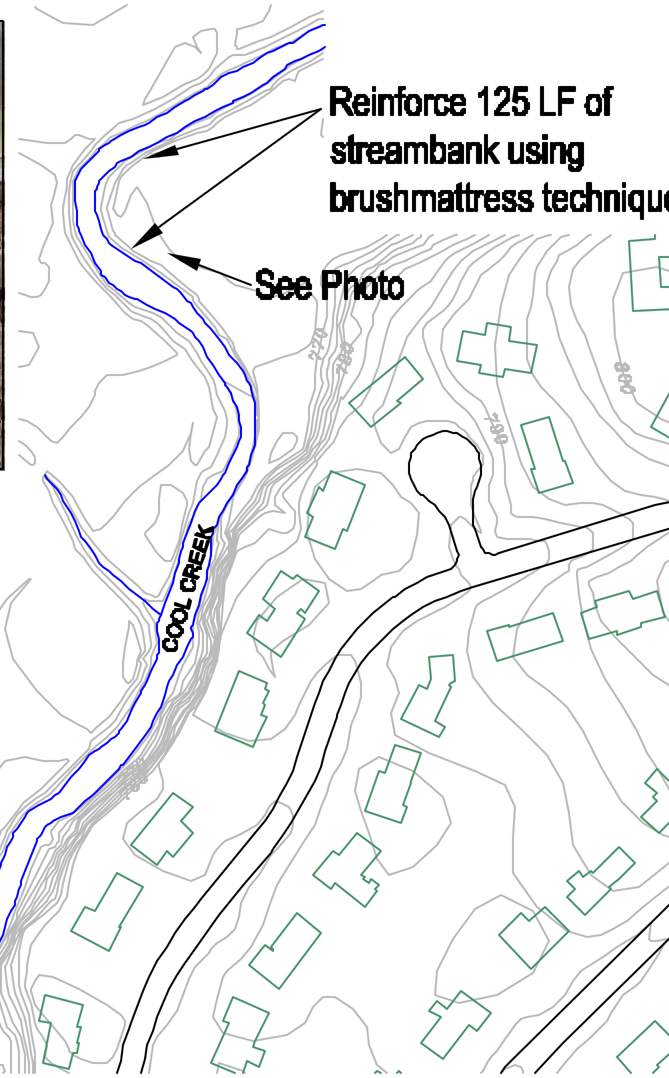
Scale: 1" = 200'

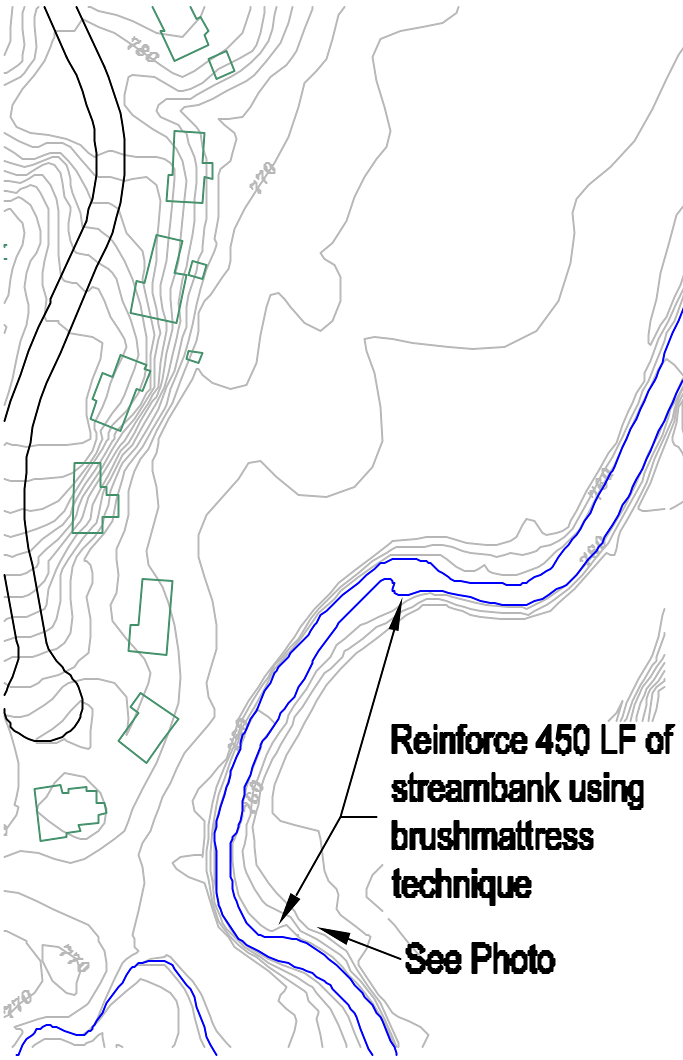
Clark Dietz

COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-14
Cool Creek
D/S of Gray Road

Cool Creek in Brookshire Golf Course
Severe Bank Erosion, Cart Path Fallen into Creek



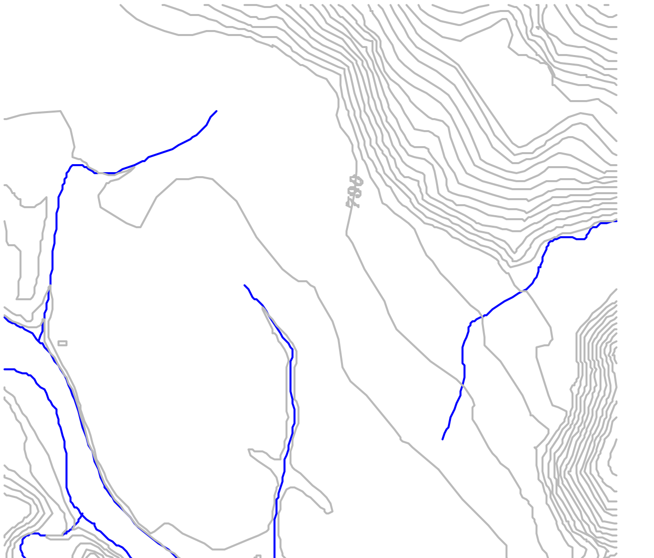


Cool Creek
Severe Bank Erosion

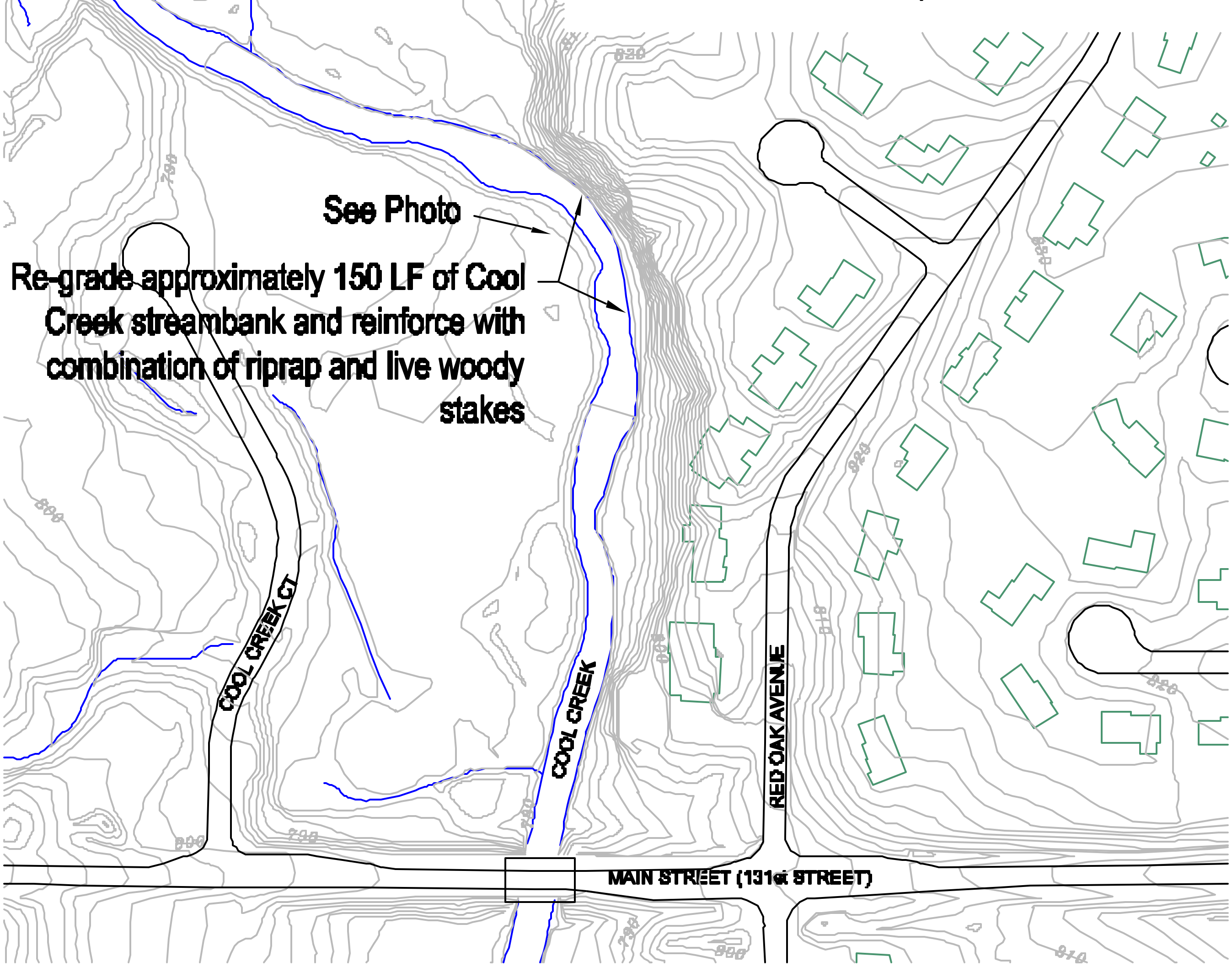
Clark Dietz

COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-15
Cool Creek
U/S & D/S of Hot Lick Creek



Cool Creek
Severe Bank Erosion, Tree Fallen into Creek

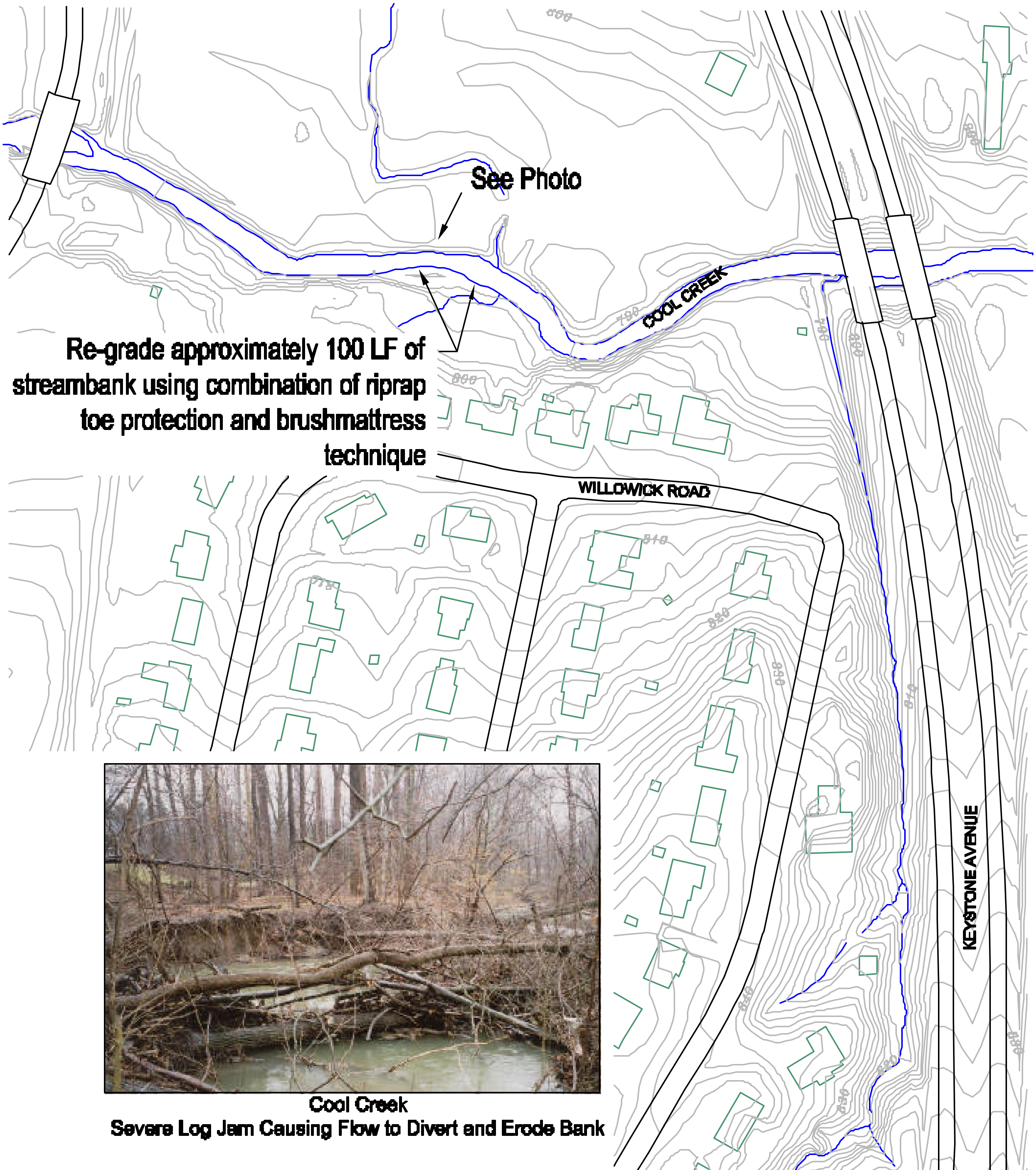


Scale: 1" = 200'

Clark Dietz

COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-16
Cool Creek
U/S of 131st Street



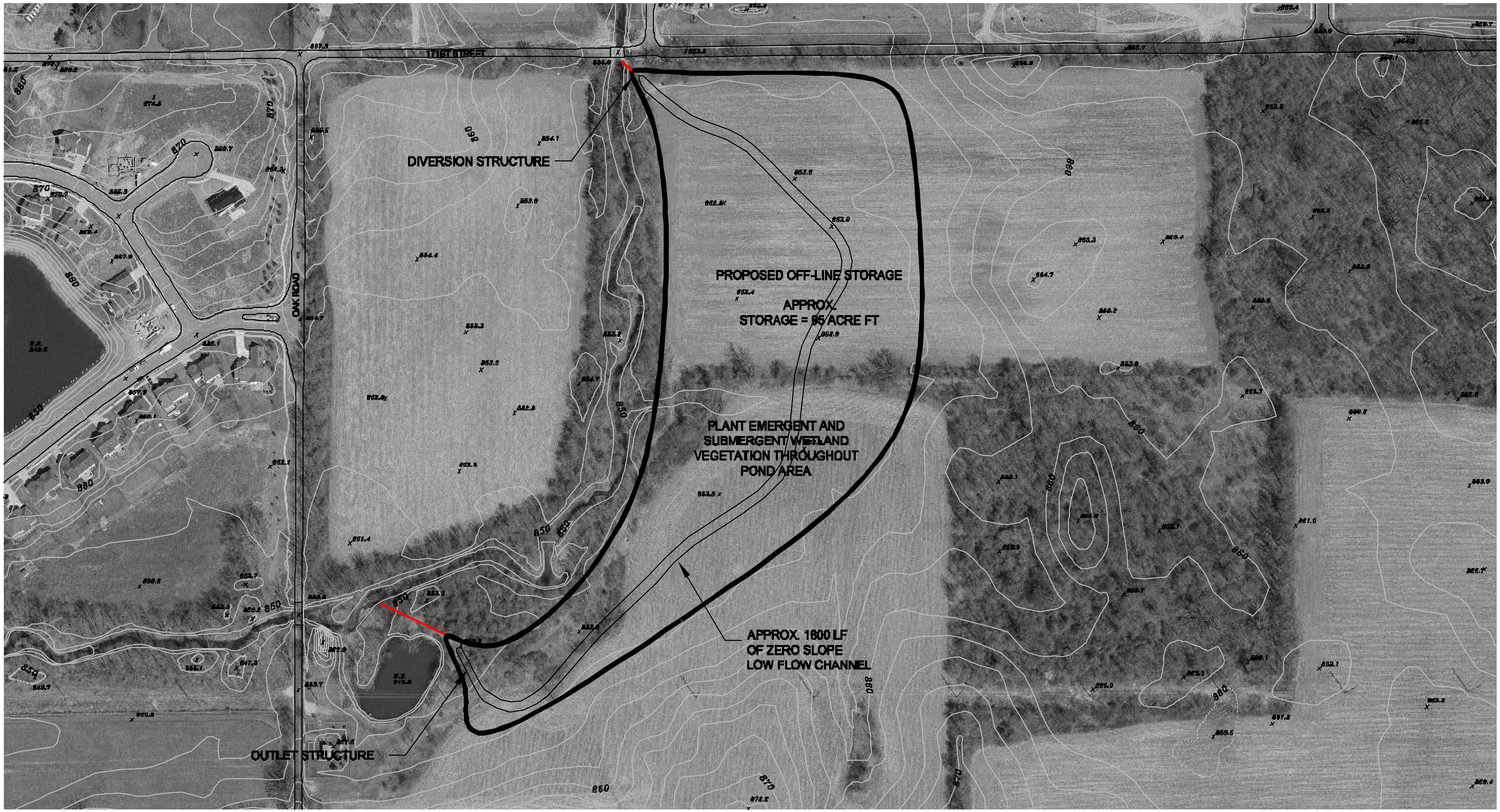
Cool Creek
Severe Log Jam Causing Flow to Divert and Erode Bank

Clark Dietz

Scale: 1" = 200'

COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-17
Cool Creek
U/S of Keystone Avenue

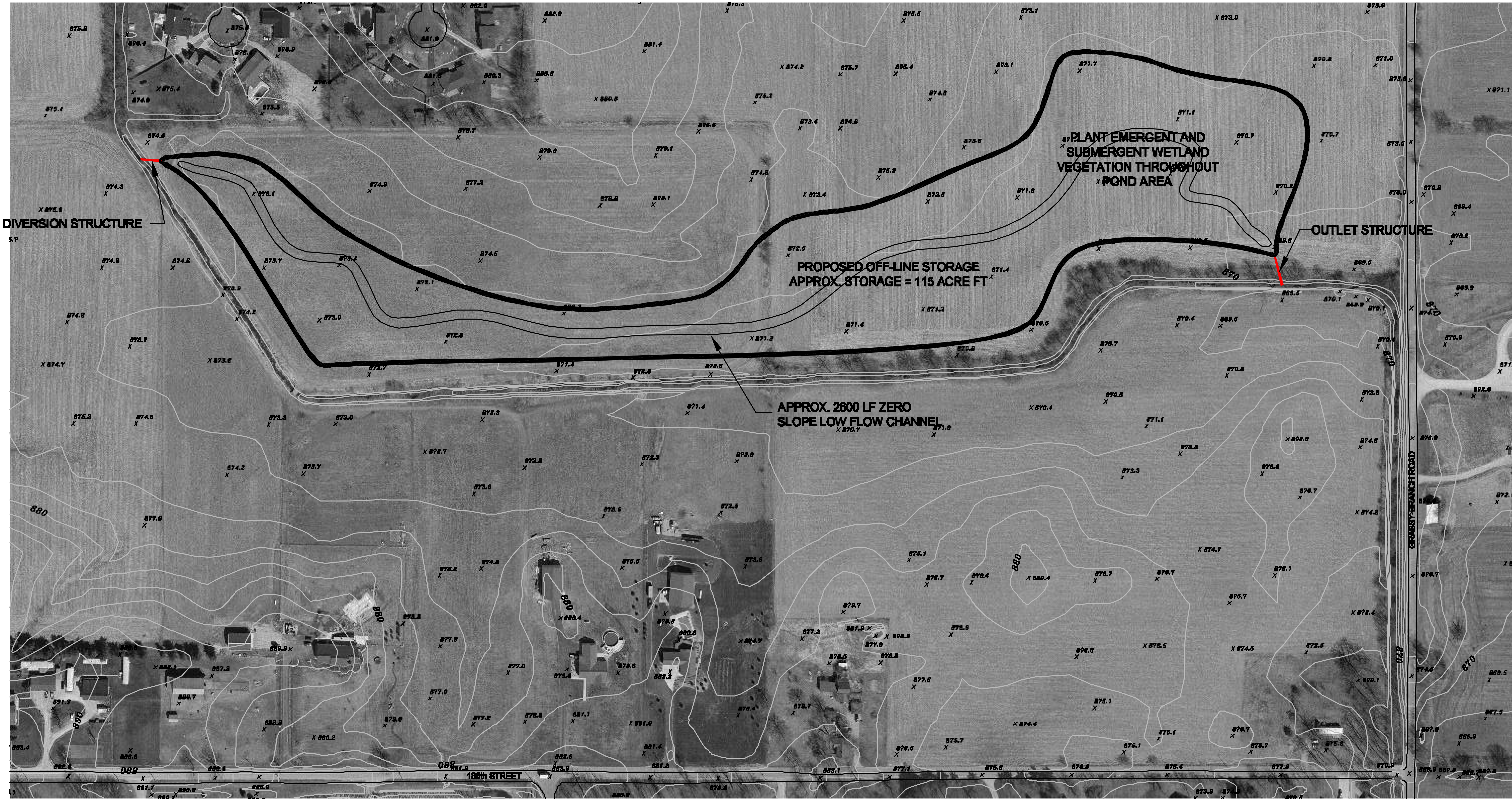


Scale: 1" = 200'

Clark Dietz

COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-18
171st Street Off-line Storage
(South Pond)



COOL CREEK WATERSHED MANAGEMENT PLAN

Figure 7-19
Grassy Branch Road Off-line Storage
(North Pond)